SURGERY OF THE
SHOULDER

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With 454 Illustrations

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This work is dedicated to my wife, Vivienne, and my sons Bruce, Barton and Brian whose patience and tolerance have made this book possible

Preface

Before any work is contemplated on the shoulder, tribute must be paid to Dr E A Codman whose meticulous and comprehensive investigation recorded in his book, *The Shoulder* has laid down the foundation for all future study in this region No one has done more to extract from the vague symptom complex the painful and stiff shoulder" the numerous heterogenous entities which it comprises His observations relative to the pathology and the management of lesions of the musculotendinous cuff subacromial bursa and his concept of the mechanism of dislocation and fracture of the upper end of the humerus have stood up under the critical assessment of many workers and now have been generally accepted His work has provided the stimulus for much painstaking research which has resulted in valuable contributions to our stock of knowledge on the shoulder A few of the more recent and outstanding contributions are the work of Inman Saunders and Abbott on the functional mechanism of the shoulder the study of McLaughlin and D Bosworth on lesions of the musculotendinous cuff and that of Hitchcock and Bechtol and of Lippmann on lesions of the tendon of the long head of the biceps brachii muscle

The writing of this book has been prompted by the desire to assemble under one cover the accumulated knowledge on the anatomy and the physiology of the shoulder and some of the more common entities responsible for dysfunction of the shoulder also to record the observations made referable to the variational anatomy and the degenerative lesions of the inner side of the scapulohumeral joint noted in successive decades Knowledge of these alterations enables one to formulate the norm for the different age periods and facilitates comprehension of the many pathologic processes implicating the musculotendinous cuff and the biceps tendon which may result in impairment of function

An attempt has been made to interpret the clinical significance of the degenerative abnormalities observed in shoulders of individuals in different decenniums For example, as will be shown in the text, wear and tear and senescence are responsible for pulling away of the labrum glenoidale from its bony attachment on the glenoid brim, this lesion increases in severity in each successive decade In the light of this information it becomes apparent that the labrum glenoidale is in no way associated with the stability of the glenohumeral joint The operations designed to restore the normal relationship of the labrum with the hope that a cure for recurrent dislocations of the shoulder will be affected are based on an erroneous premise On the other hand this same study on degenerative lesions provides an explanation of the success of some and the failure of other procedures

The observations made on a series of shoulder joints obtained postmortem from individuals on whom an examination of the extremities was made prior to their deaths are of particular clinical importance and therefore should be reported It was noted that large defects in the cuff are compatible with good function This information demands that we revise our concept of the size of a rupture of the cuff which may cause impairment of function and our present-day management of these lesions However one is well aware that the aforementioned degenerative lesions differ from traumatic rupture sustained suddenly In the former nature has ample time to rearrange the mechanics of the shoulder joint so that dysfunction does not ensue In the

latter this readjustment is lacking hence, marked impairment of function results However if given time, nature in many in stances will make the necessary alterations to restore function

Many readers may believe that the manner in which the material was obtained for the investigation on "Degenerative Lesions Compatible with Good Function" was unorthodox. That the method was such is true nevertheless in no other way can such material be obtained in sufficient quantities to allow adequate evaluation from a clinical viewpoint of the lesions found One is forced to admit that the significance of the observations justified the method

The chapter dealing with frozen shoulder and bicipital tenosynovitis emphasizes that although these are two distinct entities they are closely related Many workers do not agree with this concept however gross and microscopic studies made on many anatomic and postmortem specimens and on subjects at the operating table support this belief Whether the pathology the pathogenesis and the management recorded of the above lesions is or is not accepted it is hoped that sufficient interest will be aroused to stimulate further investigation which will either support or disprove the interpretation of the observations made in this chapter

The theory of the pathogenesis of recurrent dislocation of the shoulder is not an original one Magnuson in describing his operation for recurrent dislocation of the shoulder referred to muscular imbalance about the shoulder as the causative factor responsible for the malady This observer and many others believe that any method that will limit external rotation of the shoulder will effect a cure With this concept the author is in compl greement and makes a plea that the most simple operative procedure which will achieve restriction of external rotation of the extremity be adopted

It has been necessary to draw heavily from numerous sources in order to compile all the material deemed essential in this book Every effort possible has been made to give full credit to the authors of the material used however, it may be possible that some omissions have occurred unknowingly In such instances, the author begs to offer his apologies and expresses his regret

It is hoped that the practitioner and the surgeon will find this book a valuable source of information in the more common pathologic conditions affecting the shoulder region In addition it is hoped that the studies recorded herein will result in more adequate comprehension of the pathogenesis of these lesions increased acumen in diagnosis and more effective methods of management.

The author makes the following acknowledgments with a deep feeling of gratitude first to Dr G A Bennett Director of the Department of Anatomy of the Jefferson Medical College who together with Dr G Callery and the author, conducted the investigation on Variational Anatomy and Degenerative Lesions of the Shoulder Joint recorded in Part 1 of Chapter 3 Dr Bennett was more than a collaborator in this study He provided the stimulus necessary to guide the work to a successful termination. His profound knowledge of anatomy and its practical application, together with his keen powers of observation made possible the many significant findings noted The author is deeply indebted to Dr Bennett for the many hours of detailed instruction in the manner of approach and conduction of a problem in research also for the use of the anatomic specimens which were employed in subsequent studies in the shoulder and for the advice guidance and encouragement that he readily gave. All of the illustrations on the glenoid side of the scapulohumeral joint used in this book were obtained from the investigation conducted together with Dr Bennett and Dr Callery

Acknowledgment is also due to Dr P C Swenson Professor of Radiology Jefferson Medical College who so kindly permitted us to use all the facilities of his department

Dr R L Breckenridge, who gave valuable aid in the interpretation of the microscopic sections, Dr J B White who faithfully assisted in the study on the Lesions of the Shoulder Joint Compatible with Good Function, Dr G Diebert, Dr J Gartland and Dr T Armstrong, who helped collect the gross specimens and the case histories used in this work Dr M Blaker and Dr I Kaplan who gathered much material and prepared the bibliography and the index, Mrs M Gross, who so carefully edited the manuscript my able office staff, Miss T Everett and Miss V Quick for their painstaking work on the many drafts of the manuscript and the arrangement of the illustrations Mr A Hancock, the photographer for the Jefferson Hospital, for his conscientious and meticulous work the editor and publishers of the Instructional Course Lectures, for the privilege of using material which appeared previously in this publication, Mr C Brill, the artist, who painstakingly made all the original drawings in this work, and, finally, the J B Lippincott Company for their guidance and many suggestions in the production of this book

A. F DePalma

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Origin and Comparative Anatomy of the Pectoral Limb

ORIGIN OF PAIRED APPENDAGES

The origin of paired appendages has been the source of considerable controversy among morphologists The lateral fin theory has supplanted the gill-arch theory of Gegenbaur and is now accepted as the most plausible explanation of the beginning of these appendages

According to the lateral fin theory paired limbs are derived from longitudinal lateral folds of epidermis extending backward along the body from just behind the gills to the anus By accentuation of the anterior and the posterior and suppression and reduction of the intermediate portions of the folds the pectoral and the pelvic fins were formed (Fig 1) Into these folds muscle buds migrated from the ventral border of the adjoining myotomes giving rise to radial muscles which motivated the fins and were the forerunners of the intrinsic muscles of the hand (Bunnell) The muscle buds disclosed a metameric arrangement and derived their nerve supply from ventral roots of the spinal nerves

Peripheral nerve fibers in the base of the fin divide repeatedly giving rise to a complex plexus The number of myotomes which comprise the muscular apparatus of the fin is disclosed by the number of spinal nerves which contribute to the plexus In ontogeny, motor nerves always supply the muscles for which they were designed originally Muscles exhibiting a nerve supply from more than one spinal nerve denote combining of muscular tissue of several segments Next in the process of evolution of the appendages was the appearance of radials (cartilage rays) between the muscles buds, these provided more strength and support to the fins (Fig 2)

Concentration and fusion of the proximal (basal) ends of the radials in the fin gave rise to the basilia (basal cartilages) which extended inward into the body wall to form the most primitive girdle (Fig 3) In order to meet the requirements of a freely movable fin an articulation appeared in the basal plates Further evolution of the girdle includes fusion of the basilia of either side in the midline to form a ventral bar also included is a dorsal extension of the arch above the level of the articulation to join the axial skeleton Thus a complete girdle is formed around the body The above steps in the ontogeny of the girdle have been noted in the *Selachia* (elasmobranches) and also in *Chondrostei* and *Teleostei*

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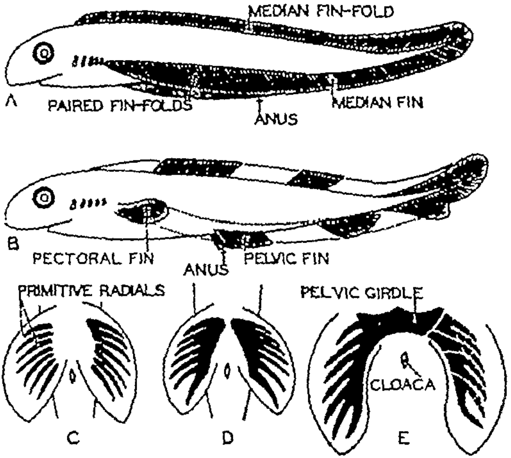


FIG 1 Hypothetical evolution of paired fins and their skeletal supports. (A) Primitive stage characterized by continuous fin folds the dorsal and ventral fins posterior to the anus are median and unpaired. (B) Elasmobranch stage paired fin folds persist only in the region of the pectoral and pelvic fins median fins have become discontinuous. (C E) Hypothetical stages in the evolution of the skeleton of the pelvic fins of elasmobranch fishes The right side of C and E represent a later stage in the phylogenesis than the left. E represents the differentiated skeletons of the girdle and the extremity (after Wiedersheim) (Neal and Rand Chordate Anatomy, Philadelphia Blakiston)

EVOLUTION OF THE PECTORAL GIRDLE

FISHES

In its basic pattern the girdle is an inverted arch *spanning the* ventral surface of the body and extending dorsally on either side above the level of the articulation Both the girdle and the limb are free Each girdle comprises a ventral segment (coracoid) and a dorsal segment (scapula) These at the point of conjuncture form the glenoid fossa *which articulates with the basal component* of the skeleton of the limb Further segmentation of the scapula gives rise to the suprascapula which may become attached to the *axial skeleton* (as *in skates*) All the above elements have separate centers of chondrification (Fig 4)

Further in the scale of evolution of the pectoral girdle is the appearance of a girdle of membranous bones derived from the skin It encircles the head starting from behind the gills *The elements of either half* of the girdle join and fuse in the midline on the ventral surface of the body through the medium of the interclavicle Each half of this membranous circle consists of four *membranous* bones (*1*) posttemporal which is jointed with the skull (2) supra cleithrum (3) cleithrum and (4) clavicle

The interclavicle which unites the girdle

ventrally is an unpaired bone Both the basal girdle and membranous girdle even tually became attached to one another Such is the basic plan of the pectoral girdle as noted in two genera (*Eusthenopteron* and *Sauripterus*) of the upper Devonian crossopterygians These are considered the ancestors of the amphibia whose appendages possessed the pattern which made the evolution of the tetrapod limb possible (Fig 5)

Amphibia

With the attainment of terrestial habits most of the elements of the membranous girdle (posttemporal and supracleithrum) decreased in size and disappeared while the cartilaginous girdle began to assume a more significant role The skull was freed of all attachment to the girdle In urodels all vestiges of the membranous girdle have disappeared

In the amphibia the tripartite type of pectoral girdle made its first appearance, the coracoid represented by the ventral bar in the fishes became segmented into the an terior procoracoid and posterior coracoid while the clavicle came in relation to the procoracoid No significant alterations occur in the suprascapula and the scapula A note worthy observation in the pectoral girdle of large amphibia (*Rhachitomi*) is the direc tion of the glenoid fossa It faces laterally indicating that the humerus extended away from the trunk in the coronal plane hori zontal to the ground Its articular surface was screw shaped (Howell) indicative of clumsy arm movement

Reptiles

Whereas in the amphibia the pectoral girdle is just behind the head in the reptile it has migrated a considerable distance from this position Essentially, the girdle com prises a scapula a procoracoid and a cora coid In general the clavicle replaces the procoracoid as evidenced by the latter s re duction in size However in some reptiles the clavicle is absent (*Crocodilia* and *Chamaeleo*) Some reptiles lost their limbs

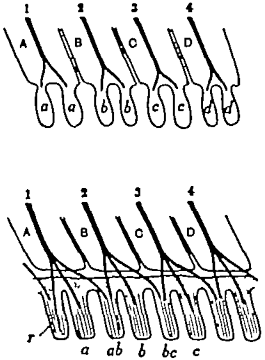


Fig 2 Formation of adult radial muscles from embryonic muscle buds and their motor nerve supply Above, embryonic stage with a pair of buds to each segment Below, adult stage with radial muscles compounded of material from adjacent buds 1-4 four spinal nerves A D four myomeres a-d, muscle buds r, radial muscle (Goodrich E. S Studies on the Structure and Development of Vertebrates, London Macmil lan, p 134)

and the girdles are either greatly reduced or have disappeared (*Amphisbaenines, Ophidia*)

Birds

Elements of the girdle of the reptiles were modified in birds to permit flight The clavicles exhibit a marked degree of development, their ventral ends fusing to form the wishbone (furcula) The scapula is small curved and narrow extending back ward The coracoid is large and strong one end together with the scapula forming the glenoid fossa while the other unites with the sternum. The keeled sternum provides attachment for the strong pectoral muscles used in flight In some cursorial birds the clavicles are greatly reduced (emu), while in others they are absent

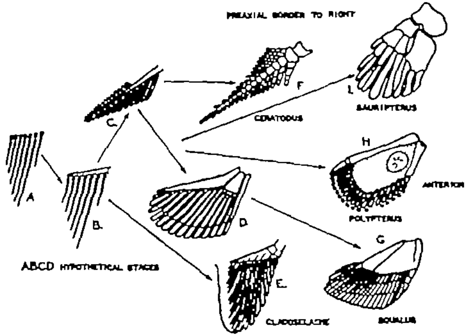


Fig 3 Diagrams illustrating hypothetical evolution of the extremities of diapnoan (I), ganoid (H) and elasmobranch (G) from a fin fold supported by a series of similar radial cartilages. By fusion of radial cartilages basilia (basal cartilages) are formed. Skeletal supports of the fins eventually differ in relation of the basal elements to the radialia (Redrawn from A Brazier Howell) (Neal and Rand Chordate Anatomy, Philadelphia, Blakiston)

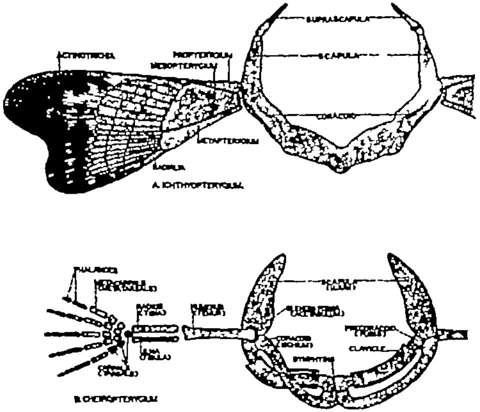


Fig 4 Diagrams illustrating scheme of pectoral appendages of lower and higher vertebrates. (*Bottom*) Names of corresponding parts of pelvic appendages are shown in parentheses. (Neal and Rand Chordate Anatomy Philadelphia Blakiston)

Mammals

In montremes the lowest order of mammals, large coracoids are found between the sternum and the glenoid fossa In all other mammals, however, the coracoid tends to become greatly reduced, forming an insignificant process on the scapula The only other vestige of the bone is the coracoid ligament, extending from the coracoid process to the bone, in which may be found isolated masses of cartilage It has a separate center of ossification This arrangement frees the scapula from any bone attachment to the skeleton In mammals without clavicles the scapula has no bony attachments whatsoever It becomes the sole support for the limb and provides attachment for muscles necessary for a freely movable extremity New functional demands on the girdle resulted in the development of a projection of bone on the dorsal surface of the scapula (spina scapulae) which extends downward and ends in the acromion

Generally the clavicle articulates with the acromion and the sternum, its only connection to the coracoid process being by the coracoclavicular ligaments (conoid, trapezoid) In mammals which have acquired freedom of the forelimb to a marked degree such as insectivores, primates and some marsupials and rodents the clavicle is usually well developed In others, including ungulates, carnivores, cetaceans and some rodents, edentates and marsupials it is absent or rudimentary

EVOLUTION OF THE UPPER EXTREMITIES

There has been considerable controversy as to the derivation of the cheiropterygium (tetrapod limb, also called the pentadactyl limb) from the icthyopterygium (paired fins of fishes) It was recorded previously that in the evolution of the free paired appendages the proximal or basal ends of the radials (cartilage rays) fused to form basilia and later with the demand of greater movability of the fin a joint appeared between the radials and the basilia, several of which in turn articulated with the girdle Such a scheme is discernible in the paired fins of the elasmobranchs, which possess three basilia (propterygium, mesopterygium and metapterygium) located between the girdle and the radials of the fin (Fig 4)

In the pectoral girdles and the fins of the crossopts, *Eusthenopteron* and *Sauripterus* (fossils from upper Devonian) is found an arrangement of the skeletal elements generally accepted as a link between paired fins of fishes and tetrapod limb (Fig 5) These two genera of crossopterygian fishes are considered close to the forms from

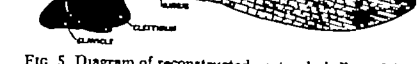
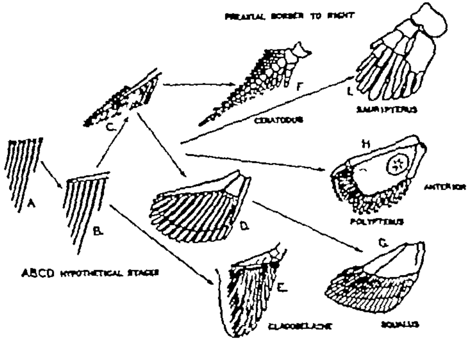


Fig 5 Diagram of reconstructed pectoral girdle and fin of *Sauripterus* and upper Devonian crossopterygian fish It exhibits a close similarity of relations of proximal elements of the extremity to those found in the pectoral extremity of tetrapods (redrawn from Brown) (Neal and Rand Chordate Anatomy Philadelphia, Blakiston)



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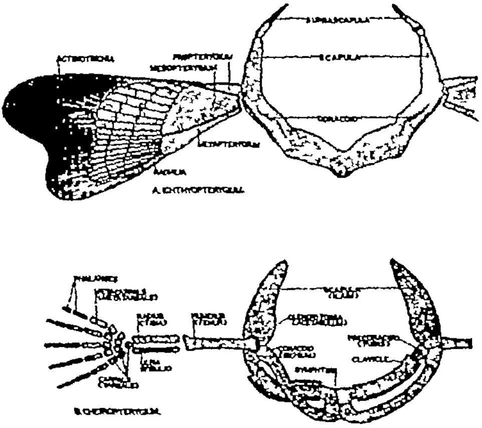

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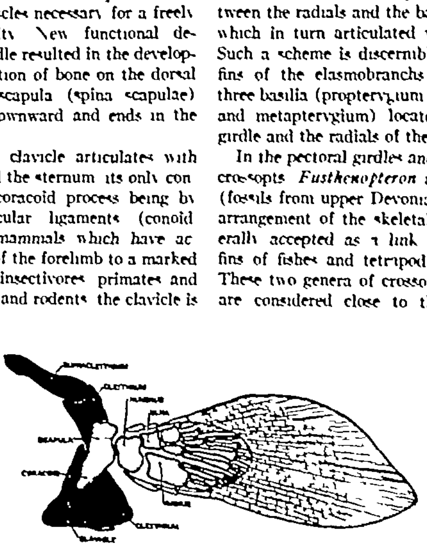

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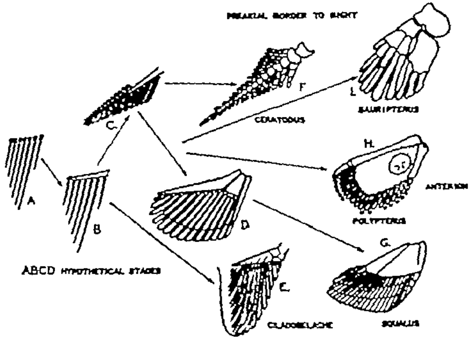

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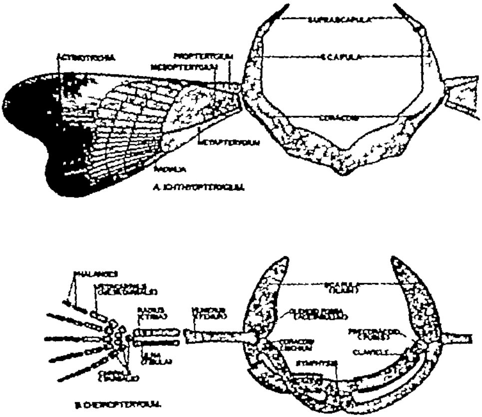


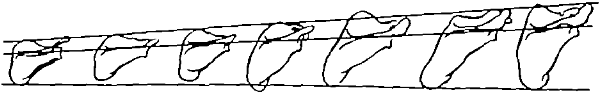
FIG 4 Diagrams illustrating scheme of pectoral appendages of lower and higher vertebrates (*Bottom*) Names of corresponding parts of pelvic appendages are shown in parentheses (Neal and Rand Chordate Anatomy Philadelphia Blakiston)

shifting from a position directed laterally to one directed posteriorly and inferiorly As a result of the change in posture, the coracoid s function decreased Hence, a gradual reduction in its size is noted in this group Up to this stage in evolution of the pectoral girdle no evidence of a spine on the dorsal surface of the scapula is found except in the Therapsida whose posture is not unlike that of the mammals

Posture was responsible for the development of the scapular spine which is found in all mammals except the very primitive forms the Monotremata With rearrangement of some and disappearance of other muscles the need of a procoracoid and coracoid no longer existed Therefore the former element disappeared entirely, while the latter was reduced to the coracoid process The shape of the scapula is dependent upon posture and the functional requirements of the muscles attached to it It is broad and massive in forms which need large powerful serratus anticus muscles to support heavy bodies in a quadruped position

In mammals which have partially or completely freed the pectoral limbs, the shape of the scapula exhibits a trend toward the pattern found in man These alterations are brought about by change in posture from the pronograde to the orthograde and highly specialized functional requirements of a prehensile limb The most significant scapular change is in the relation of length to breadth of the bone Pronograde forms disclose a long narrow scapula, while in the ascent toward man it becomes broader

This morphologic change is most obvious in the primates That portion of the scapula below the spine demonstrates the most pronounced alterations, those in the region above the spine being insignificant Morphologic modifications in the scapula can



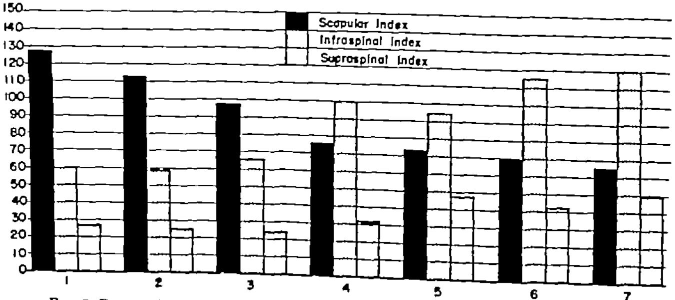


FIG 7 Progressive decrease in scapular index in successive stages from the pronograde to the orthograde (Redrawn from Inman Saunders and Abbott J Bone & Joint Surg 26 2)

which the amphibia evolved The basic pattern of their pectoral limb comprised a proximal segment which was jointed to two middle segments which in turn articulated with several distal elements The proximal element was destined to become the humerus the middle elements the radius and the ulna the distal elements the carpus and the digits

The change from an aqueous to a terrestrial existence was accompanied by pronounced alteration in the skeletal elements of the pectoral fin which now must be used for support and locomotion. Therefore in the amphibia, the first animals to adopt terrestrial habits the pentadactyl limb evolved from the paired fins From the distal element arose the carpus the metacarpus and the phalanges The principal element in the radial side became the thumb and those on the ulnar side the other four digits In all stages of evolution up to and including man the basic plan of the pentadactyl limb was maintained

Scapula

During the evolution of the upper extremity, the scapula more than any other bone of the shoulder girdle reflects momentous alterations that have been brought about by increased functional demands of a prehensile limb Changes in posture provided the stimulus which initiated the numerous morphologic changes In the amphibia the scapula was high in the cervical region but was freed from the skull Rhachitomous amphibians possessed massive scapulae with the glenoid cavity pointing laterally The articulating surface was screw-shaped and the limbs were held in the coronal plane horizontal to the ground

In the Reptilia the scapula with the entire girdle migrated a great distance from the skull in order to permit a more efficient mode of locomotion The scapula was still broad and massive in the primitive forms However later with increased efficiency in locomotion there was a trend toward reduction of this bone the glenoid cavity

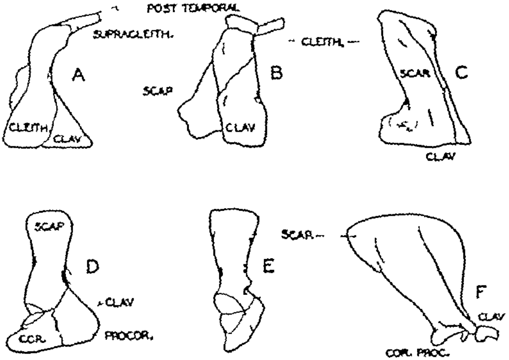


Fig 6 Phylogenesis of the pectoral girdle (A) Sauripterus (Devonian crossopterygian lung fish) (B) Eogyrinus (Carboniferous embolomerous amphibian) (C) Eryops (Permian rhachitomous amphibian) (D) Moschops (Permian dinocephalian reptile) (E) Cynognathus (Triassic theriodont reptile) (F) Macaca (an Old World Recent monkey) (Howell Speed in Animals, University of Chicago Press p 138)

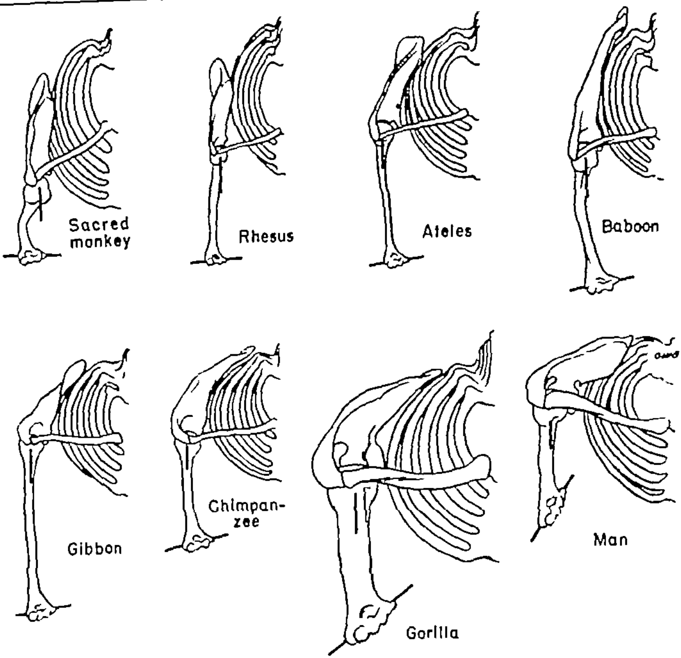


FIG 9 Changes in the thoracic cage the scapula and the humerus, in successive stages from the pronograde to the orthograde. The thoracic cage shows flattening in the antero-posterior plane and the scapula migrates to a dorsal position so that the glenoid cavity is directed laterally The humerus shows a progressive increase in the torsion angle.

nence of the outer end of the spine the acromion process Whereas in pronograde forms the acromion process is insignificant, in orthogrades it is a massive structure overlying the humeral head (Fig 8)

HUMERUS

During evolution of a prehensile extremity profound morphologic modifications occurred in the humerus In rhachitomous amphibians the humerus was a massive bone flattened at either end the distal end being larger than the proximal to provide attachment for large forearm muscles In reptiles with free motion in the forelimb the upper extremity was brought beneath the body, and the humerus became less massive Two nodules appeared at the proximal end which evolved into the tuberosities of the mammalian humerus The anterior became the greater and the posterior the lesser tuberosity

Generally speaking in mammals adapted for running (ungulates—horse) the articu

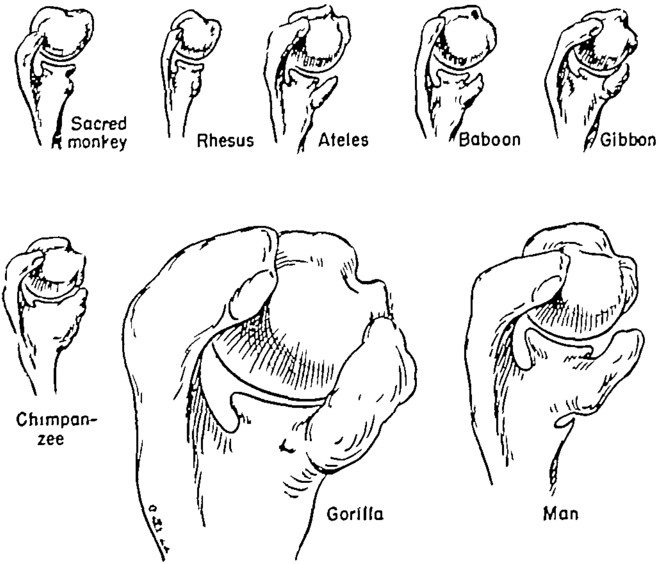
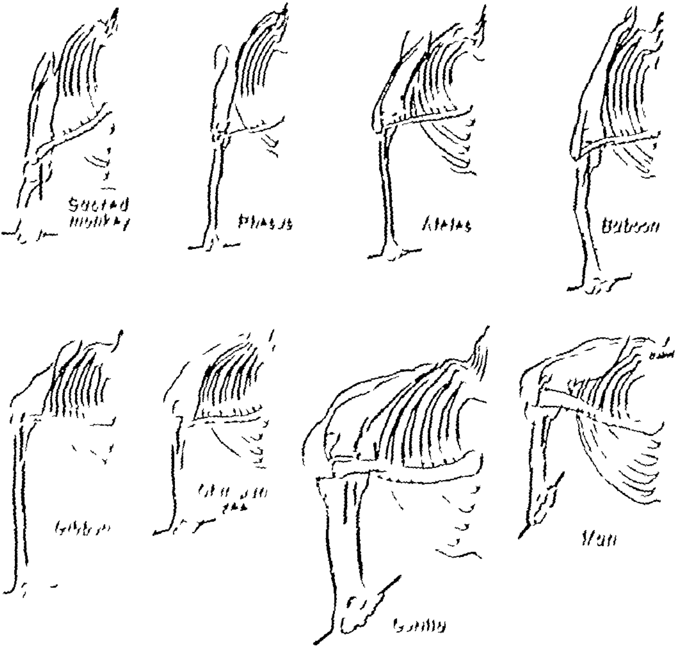


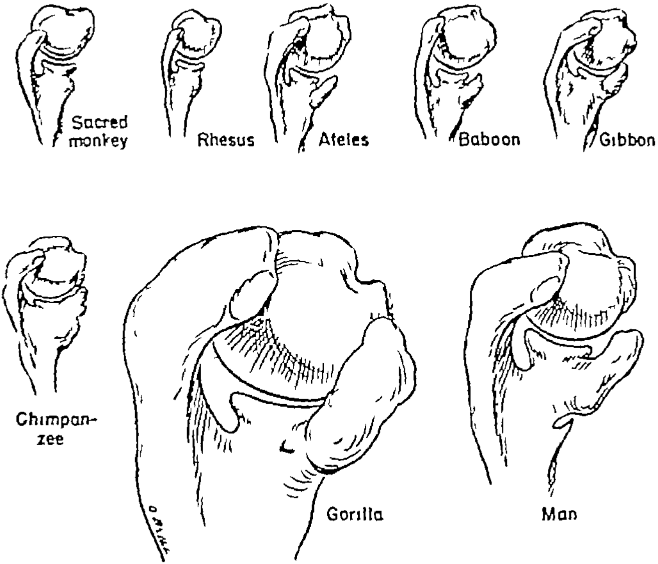
FIG 8 Gradual increase in spine of the scapula and the acromion process during development from the pronograde to the orthograde. This change reflects the increasing importance of the deltoid muscle. Also note the increase in size of the coracoid process the inequality of the two tuberosities of the head of the humerus and the inner displacement of the intertubercular sulcus in successive stages of development

be expressed by a scapular index, a ratio of the breadth (measured along the base of the spine) to the length (measured from the superior to the inferior angle) The *scapular index is high in the pronograde* in which the scapula is long, narrow and slender The index progressively decreases in the successive stages of development approaching man (orthograde)

This is the result of a gradual increase in the breadth of the scapula and elongation of the bone below the level of the spine giving rise to a progressive increase in the "infraspinous index (Fig 7) Inman Saunders and Abbott, in their comprehensive study of the function of the shoulder joint observed that lengthening of the scapula below the spine changed the relation of the axillary border of the scapula to the glenoid fossa, thereby altering the angle of pull of the muscles attached to this region a feature of great significance in the mechanism of the shoulder

In the primates as one approaches man, the increasing importance of the role of the deltoid muscle is reflected in the promi


Sacred monkey
Rhesus
Ateles
Baboon
Gibbon
Orang utan
Gorilla
Man



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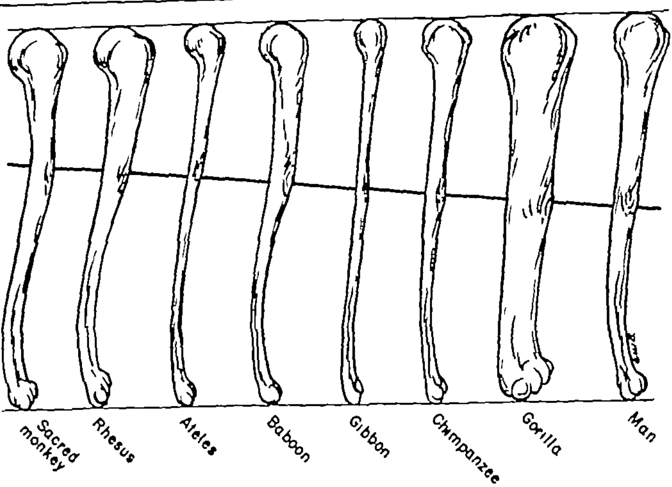


FIG 11 Deltoid insertion migrates progressively to a lower level on the shaft of the humerus, indicating the significant role played by the deltoid in higher primates.

to a more distal position This feature together with increase in size of the acromion, greatly increases the leverage of the deltoid muscle (Fig 11)

Other significant morphologic alterations were recession of the lesser tuberosity and medial displacement of the bicipital groove Pronograde forms disclose the biceps tendon passing over the center of the head of the humerus and entering the groove in the same plane In this position it acts as a strong elevator of the arm Both tuberosities in these forms are approximately the same size

A different relationship is found in orthogrades In these forms the bicipital groove has been rotated medially by torsion of the humerus so that a line passing through the center of the head of the humerus in man makes an angle of 30° with one passing through the plane of the groove (Inman Saunders and Abbott) Marked reduction in the size of the lesser tuberosity is a characteristic feature in the higher primates

From the above observations it is obvious that the biceps tendon (long head) functions at a greater mechanical disadvantage, further increased by using the arm in a position of internal rotation In this position the biceps tendon plays over the medial wall of the groove and the lesser tuberosity now really functions as a trochlea

MUSCLES

Changes in posture and functional requirements of a prehensile extremity were responsible for alterations in the topography and the morphology of muscles about the shoulder Such changes were primarily responsible for the skeletal modifications previously indicated The extent of the change in any individual muscle becomes apparent when its relative mass is compared with the total mass of the group in

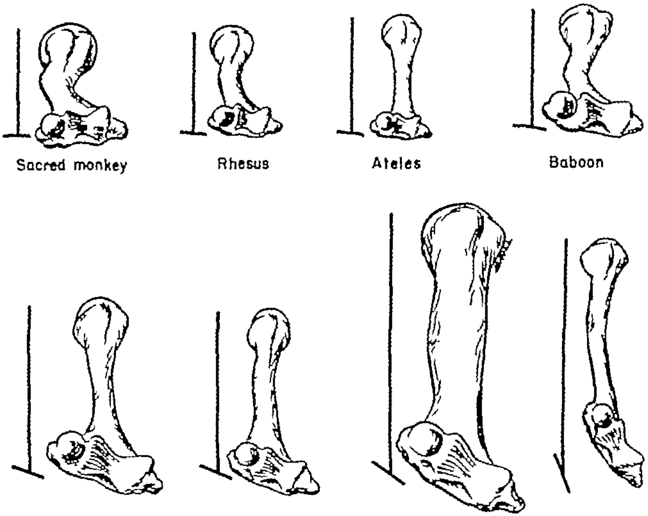
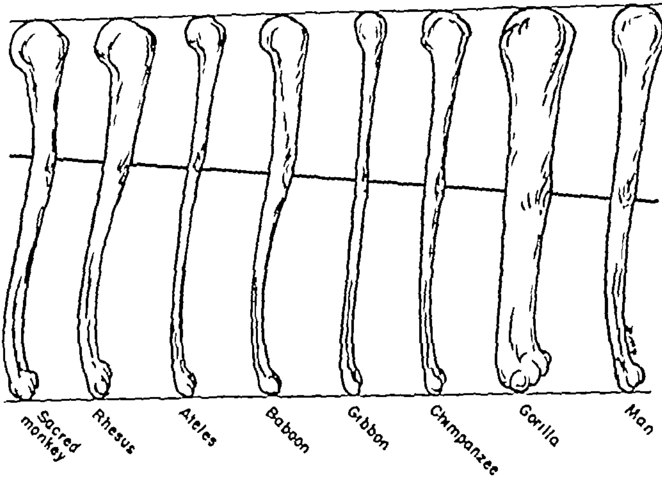


FIG 10 Progressive increase in torsion of the humerus resulting in inward rotation of the bicipital groove The articular surfaces at either end of the humerus rotate in opposite directions.

lar surface of both ends of the humerus function in the same plane (sagittal plane) a line passing through the long axis of the head of the humerus is directed forward and one through the distal articular surface transversely Meeting of these two axes describes a torsion angle of 90° In primates as the orthograde form is approached, the torsion angle increases Man discloses some variation in the torsion angle Australians exhibit an angle of 134° and the French and the Swiss 164° (Martin 1928)

Several factors are responsible for the changing relationship of the articular surfaces of the humerus Development of the orthograde forms was accompanied by anteroposterior flattening of the thoracic cage and dorsal displacement of the scapula The glenoid fossa is now directed laterally (Fig 9) Prehensile requirements however demand that the extremity as a whole function anterior to the body and that the elbow be maintained in the parasagittal plane To meet these specifications the humeral shaft twists inwardly while the articular surfaces at either end rotate in the opposite directions (Fig 10) The dominant role acquired by the deltoid in the higher primates is demonstrated further by the progressive shift of the deltoid insertion on the humerus



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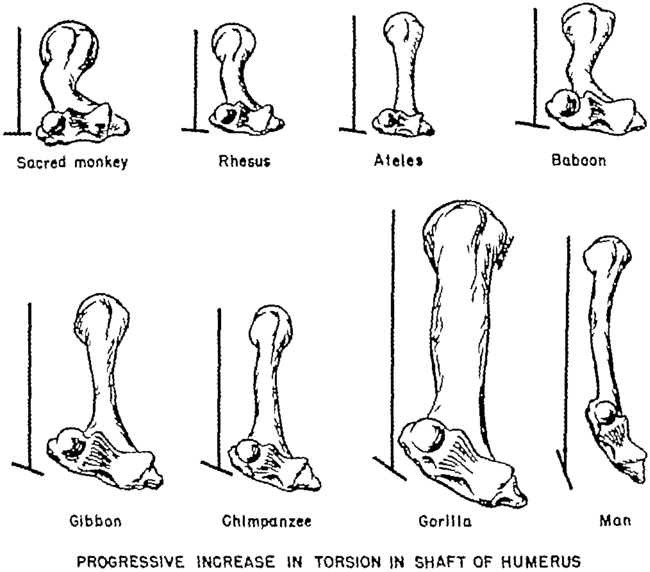

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which it belongs. Following the scheme of Inman, Saunders and Abbott, the muscles which partake in shoulder mechanism can be categoried into three topographic units (1) scapulohumeral group (2) axiohumeral group and (3) axioscapular group

The study made on the functional mechanism of the shoulder by the aforementioned workers is so complete, comprehensive and logical that one is forced to draw heavily from this source of information when discussing this topic. Many of their observations are noted in the subsequent section.

THE SCAPULOHUMERAL GROUP These connect the scapula to the humerus and consists of the supraspinatus infraspinatus teres minor subscapularis and deltoid muscles Concurrently with acquisition of a free limb the relative deltoid mass increases while that of the supraspinatus decreases Forty-one per cent of the total mass of this unit in man is made up by the deltoid muscle

Comparative anatomy further discloses that the teres minor muscle is wanting in early mammals and that it evolved from the deltoid to form a separate muscle passing from the inferior angle of the scapula to the humerus With elongation of the infraspinatus portion of the scapula the relative mass of this muscle progressively increased until in man it makes up 5 per cent of the total mass Although it is a morphologic component of the deltoid the teres minor because of topographic changes plays an entirely different role in the mechanism of the shoulder than that of the deltoid.

The subscapularis muscle is little affected by morphologic alterations from the primitive to the higher primates. It makes up 20 per cent of the mass of the scapulohumeral group. The only significant alteration is an increase in number of fasciculi of origin This is the result of elongation of the scapula. This same skeletal change brought about an increase in the area of attachment of the infraspinatus which constitutes approximately 16 per cent of the total mass

According to Inman Saunders and Abbott the last three muscles (subscapularis teres minor and infraspinatus), by reason of alterations in the morphology and the topography of the group and the elongation of the scapula function as a unit. They are both rotators and depressors of the head of the humerus.

The axioscapular group chiefly concerned with the mechanism of the shoulder, comprises (1) serratus anterior, (2) rhomboids, (3) levator scapulae and (4) trapezius muscles The first three muscles of this unit originated from one complex of muscle fibers arising from the ribs (first eight or ten) and their homologues (transverse processes of the cervical vertebrae) in the cervical region and inserting into the vertebral border of the scapula. In primitive forms the dominant function of this group was to control the movements of the vertebral border of the scapula.

In general those fibers concerned with dorsal motion of the scapula became the rhomboid muscles those with ventral motion the serratus muscle and those with cranial displacement of the scapula the levator scapulae Function and posture were responsible for evolution of the individual muscle as they exist in the higher primates The serratus anterior formed the basal unit for all three muscles Concentration of the proximal and distal fibers and progressive reduction of the intermediate fibers gave origin to two distinct muscles the levator scapulae and the serratus anterior

Further morphologic alterations in the serratus anterior comprise grouping of its proximal and distal fibers progressive reduction in size of its intermediate fibers and insertion of the dominant upper and lower portions of the muscle into the superomedial and inferior angles of the scapula

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The axiohumeral group is made up of the pectoralis major the pectoralis minor and the latissimus dorsi muscles and extends from the trunk to the humerus The pectoral group evolved from a primitive muscle sheet which connected the coracoid with the humerus Change in posture and increased functional demands made on the limb were responsible in the later reptilian and early mammalian forms for displacement of part of this muscle sheet dorsally to gain attachment to the scapula which later gave rise to the supraspinatus the infraspinatus and the anterior part of the subscapularis All other components of the muscle migrated from the procoracoid to the sternum and gave rise to the pectoralis major

Further morphologic modification in the pectoralis major resulted in a division of this mass into a superficial and a deep layer Part of the sternal attachment of the superficial fibers shifted forward and gained attachment to the clavicle (clavicular head of the pectoralis major) From the deep layer evolved the pectoralis minor muscle which in higher primates discloses its humeral attachment in primitive forms to have migrated to the coracoid process

The latissimus dorsi and teres major muscles originate from a single basic muscle sheet extending from the trunk caudal to the scapula to the humerus They demonstrate in the higher primates no significant morphologic or topographic alterations except that they are unusually well developed in forms specializing in climbing

Biceps Brachii and Triceps Muscles. Both these muscles evolved from ventral and dorsal brachial muscle elements which were concerned primarily with motion in the more distal joints the elbow and the wrist From the ventral brachial elements arose the biceps muscle by proximal migration along a fascial plane of brachial components to reach the scapula (Howell) In mammals other than primates it is a single muscle Cursorial forms (horse) disclose powerful biceps which together with the supraspinatus act as a single functional unit to elevate the foreleg

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2

Normal Anatomy and Functional Mechanism of the Shoulder Joint and Congenital Abnormalities

- SHOULDER JOINT
- SCAPULOHUMERAL (GLENOHUMERAL) JOINT
- LIGAMENTS OF THE SHOULDER JOINT
- BURSAE AROUND THE SHOULDER JOINT
- STERNOCLAVICULAR JOINT
- ACROMIOCLAVICULAR JOINT
- TERMINOLOGY OF MOVEMENTS AT SHOULDER JOINT
- ANATOMIC POSITION OF THE EXTREMITY
- SCAPULOHUMERAL RHYTHM
- MOTION AT THE SHOULDER JOINT
- MECHANICAL FORCE REQUIREMENTS FOR MOTION AT THE SHOULDER JOINT
- PRACTICAL SIGNIFICANCE OF MUSCLE FORCE COUPLE PRINCIPLE
- GLIDING MECHANISM OF BICEPS TENDON
- IMPAIRMENT OF MUSCLE FORCE COUPLE BY ISOLATED NERVE PARALYSIS AND OTHER LESIONS
- CENTERS OF OSSIFICATION OF THE HEAD OF THE HUMERUS
- CONGENITAL ANOMALIES

The accumulation of knowledge referable to the basic principles which govern the intricate mechanism of the shoulder makes it evident that the term "shoulder joint" needs clarification. Hitherto the term has been used loosely in many textbooks to designate the scapulohumeral articulation. Comprehensive analysis of the functional mechanism of the shoulder discloses, however, that the scapulohumeral articulation is only one component of a complex system which functions synchronously to produce precise, coordinated movements.

From a functional viewpoint, the shoulder joint comprises four distinct articulations: the scapulohumeral, the sternoclavicular, the acromioclavicular and the scapulothoracic. Although the last structure is not a true joint anatomically, it must be considered as such functionally (Fig. 12).

Discussion of the anatomy of the shoulder joint should include more than a description of the topography of the numerous components. Any such discussion should embody the modern concepts of the functional mechanism of the shoulder, an understanding essential to the orthopedic surgeon in designing operative procedures to restore optimum function and power in a shoulder joint whose function has been severely impaired. Moreover, knowledge of the origin and the morphologic and topographic modifications that have occurred in the evolution of man's prehensile extremity facilitates comprehension of the basic principles involved in the above mechanism of function.

A discussion of this region would be incomplete without recording the numerous variations of normal anatomy of the inside of the scapulohumeral joint, recognition of which is imperative for the correct evaluation and therapy of pathologic processes commonly encountered in this region. These variations are of sufficient importance to

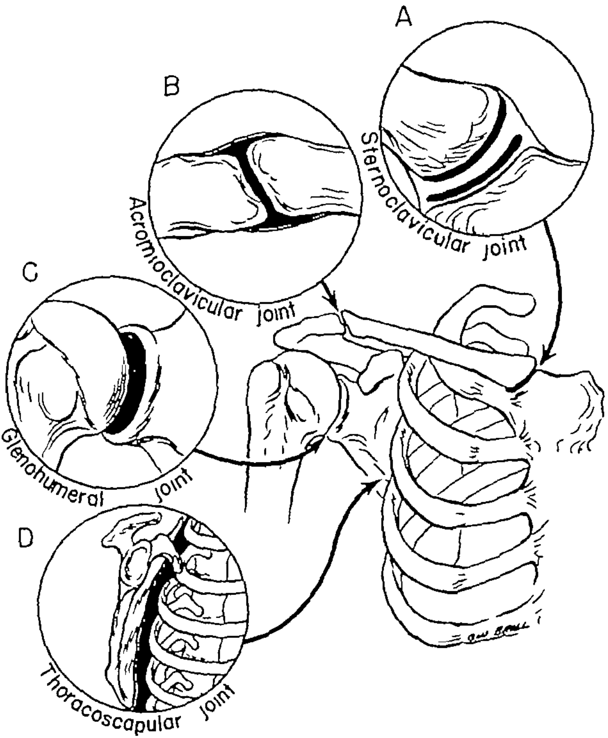

FIG. 12 Functional components of the shoulder joint. (A) Sternoclavicular joint. (B) Acromioclavicular joint. (C) Glenohumeral joint. (D) Thoracoscapular joint.

merit discussion in a separate chapter entitled Variational Anatomy and Degenerative Lesions of the Shoulder Joint

SHOULDER JOINT

As previously noted the shoulder joint from a functional viewpoint comprises four articulations (1) scapulohumeral (2) sternoclavicular (3) acromioclavicular and (4) scapulothoracic joints All four perform simultaneously as a single unit, yet are capable of independent motion (Fig 12)

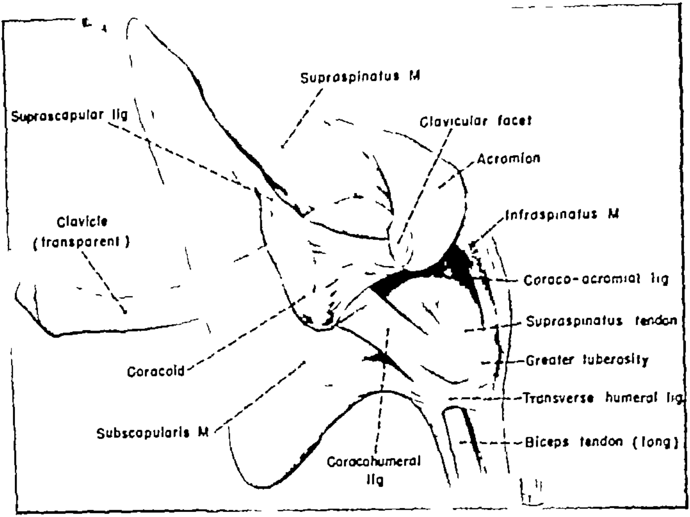

FIG 13 Coraco-acromial arch overhanging the head of the humerus Observe that the acromion is broad flat and massive the oval clavicular facet faces obliquely upward and the triangular coraco-acromial ligament extends from the horizontal portion of the coracoid process to the tip of the acromion lateral to the clavicular facet

SCAPULOHUMERAL (GLENOHUMERAL) JOINT

SCAPULA

The scapula has come to assume a most pertinent role in the functional mechanics of the shoulder joint Topographic and morphologic alterations in its musculature are reflected in its size configuration and position. It lies on the posterior surface of the thorax, suspended from the cervical and upper thoracic vertebrae by strong axioscapular muscles (levator scapulae, rhomboids and upper digitations of both the trapezius and the serratus anterior muscles)

At rest with the arm at the side its superior angle is opposite the superior border of the second rib, while its inferior angle is opposite the seventh intercostal space It is almost completely enveloped in muscle masses. The ventral surface is slightly concave, conforming to the convex surface of the upper and posterior region of the thorax. Normally the scapula has a wide excursion over the posterior chest wall It is free of any bony attachments to the axial skeleton except through the clavicle which serves as a strut between the scapula and the sternum In man elongation or extension of the infraspinatous portion of the scapula has resulted in a decreased scapular index compared with that of other primates On the other hand the infraspinatus index has increased (Fig 7)

A triangular projection of bone the spine

of the scapula, lies on the dorsal surface of the scapula. It is directed outward and slightly upward and terminates in the acromion process The blade of the scapula is thin and delicate, while its bony projections (acromion, coracoid, spine head and neck) are strong

Acromion Process

The spine of the scapula terminates in the acromion process, a prominent massive, flat bony projection which overhangs the humeral head from behind Its superior flat surface slants outward backward and downward The acromion articulates with the clavicle by means of an oval elongated articular facet facing obliquely upward Anterior to the articular facet, the acromion receives the outer end of the coraco-acromial ligament (Fig 13)

The acromion forms the outer bony component of the coraco-acromial arch It is important to visualize the topographic anatomy of this bony process As will be shown later it plays a major role in the mechanism of shoulder movements traumatic and degenerative lesions of the head of the humerus and the musculotendinous cuff and lesions of the subacromial bursa Moreover it protects the humeral head from impacts from behind and above

In elevation of the arm the humeral head and tuberosities pass beneath the acromion It is impossible to traumatize the humeral head directly unless a blow is directed to the front and the top of the shoulder while the arm is at the side and the elbow pulled backward (position of dorsal flexion) According to Grant 21 per cent of adult scapulae exhibit failure of fusion of the acromial epiphysis with the acromion

Coracoid Process

The coracoid process is crooked curved stubby and bony and arises from the neck of the scapula just behind and to the inner side of the glenoid fossa. It is directed forward outward and downward Running transversely just above the coracoid is the outer third of the clavicle, to which it is connected by the strong coracoclavicular ligaments (trapezoid and conoid ligaments) The coracoid process overhangs the humeral head anteriorly, as the acromion does posteriorly The inner end of the coraco-acromial ligament is attached to the outer side of the upper aspect of the coracoid

Glenoid Cavity

This shallow fossa is shaped like an inverted comma Its superior portion, which is designated the tail of the comma, is narrow, the inferior (head of the comma) is broad It faces forward and upward and is covered by hyaline cartilage, which is thinner in the center of the head of the comma than at the outer margins of the articular cavity

A fibrocartilaginous structure, the labrum glenoidale, triangular in cross section, surrounds the periphery of the glenoid cavity In infant shoulders this structure is closely attached by its base to the brim of the glenoid cavity, its glenoid edge blending with the fibrils of the hyaline cartilage, while its capsular border is continuous with the fibrous capsule. In older decades the labrum in the region of the tail of the comma rests on the edge of the glenoid fossa like a meniscus, its glenoid border lying free (Fig 14)

These anatomic features and their significance are discussed in detail in the following chapter The long head of the biceps tendon inserts into the supraglenoid tubercle and is continuous with the posterior and anterior fibers of the labrum in the superior region of the tail of the comma (Fig 14)

Humerus

The spherical head of the humerus rests on the shaft at an angle its articular surface directed backward medially and upward Only a small portion of the head is in contact with the glenoid fossa at any one time during motion or at rest. Inward torsion of the shaft of the humerus has displaced the tuberosities and the bicipital groove medi

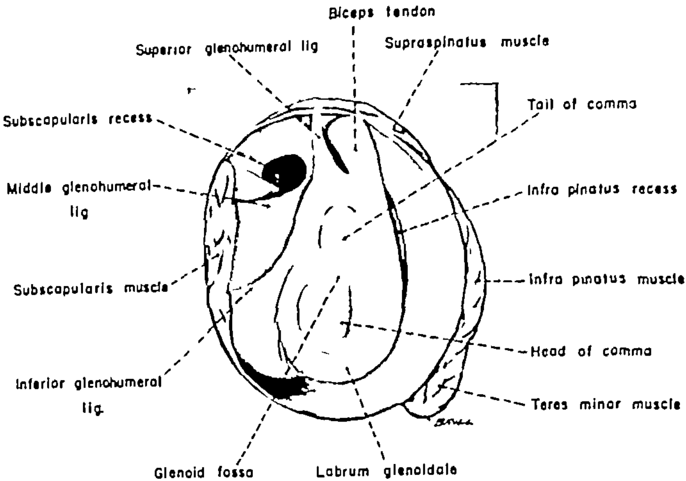

FIG 14 The glenoid cavity is shaped like an inverted comma Observe the superior the middle and the inferior glenohumeral ligaments on the superior and the anterior aspects of the joint converging toward the biceps tendon Also note the superior subscapularis recess (subscapularis bursa) situated immediately above the middle glenohumeral ligament. *The biceps tendon blends with the fibers of the labrum glenoidale* A small recess in the posterior aspect of the joint forms the infraspinatus recess It does not exist in all joints.

ally The humeral torsion angle varies from 134° to 160° (Figs 9 and 10) The bicipital groove is displaced medially 30° from a line passing through the center of the head of the humerus The greater tuberosity is directed externally forming the outer wall of the bicipital groove the lesser tu*berosity is directed forward and forms the* inner wall of the groove Between the tuberosities and the edge of the articular surface of the anatomic head is a broad sulcus called the anatomic neck of the humerus

In living subjects the sulcus is obliterated by the musculotendinous cuff which completely fills this groove It is very much in evidence in humeri stripped of all soft tissue structures. There is a gradual recession of this cuff from its line of insertion in shoulders of individuals past middle life It is not uncommon to see in these shoulders (when viewed from the inside of the joint) bare portions of the anatomic neck between the edge of the articular cartilage of the humeral head and the receding cuff Such lesions were designated "rim rents' by *Codman*

During elevation of the arm the greater tuberosity glides under the acromion or coraco-acromial arch with ease However in lesions which produce hypertrophy of this bony process the tuberosity impinges on the acromion or the coraco-acromial arch thereby restricting the range of motion or causing a painful jog as it passes beneath the overlying structures As will be shown in the discussion on motion at the shoulder

complete elevation can be achieved only in the frontal plane with the arm in internal rotation and in the coronal plane with the arm in external rotation

Clavicle

The clavicle is interposed between the acromion process and the sternum It exhibits a double curve being thick and cylindrical at the inner end and broad and flat at the outer end It is generally believed to form a strut between the scapula and the axial skeleton holding the upper extremity away from the body so that it can perform in the parasaggital plane. Nevertheless it has been demonstrated clinically that resection of part or all of the clavicle does not allow a forward droop of the scapula.

One is forced to conclude that the axioscapular group of muscles are capable of maintaining the scapula in its normal dorsal position without the anterior bony strut. Through the joints at either end, the clavicle is capable of a wide range of motion which is essential to achieve complete elevation of the arm The clavicle is bound to the coracoid process by the coracoclavicular ligaments, whose fibers permit considerable rotation in its long axis It provides attachment to the upper digitations of the trapezius which elevates and supports the shoulder and to the deltoid and the pectoralis major (clavicular head) which participates in elevation of the arm

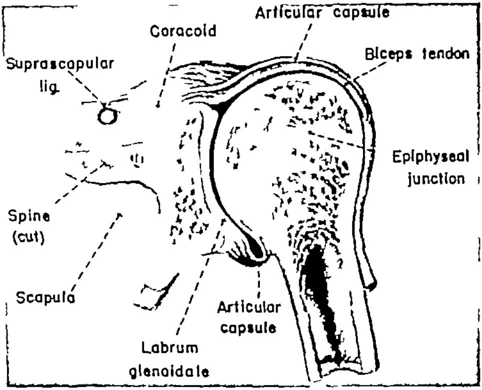

Fig 15 Frontal section of the right shoulder joint, posterior view Observe the redundancy of the capsule on the inferior aspect of the neck of the humerus. The fibrous capsule is lined with synovial membrane which is prolonged around the tendon of the long head of the biceps muscle as far as the surgical neck of the humerus providing a synovial cover for the osseofibrous bicipital tunnel It then ends as a blind sac and is reflected upon the tendon (Redrawn from S W Spalteholz Hand Atlas of Human Anatomy Philadelphia Lippincott)

Articular Capsule of Scapulohumeral Joint

The fibrous capsule is a loose redundant structure twice the surface area of the humeral head (Fig. 15) Posteriorly and in

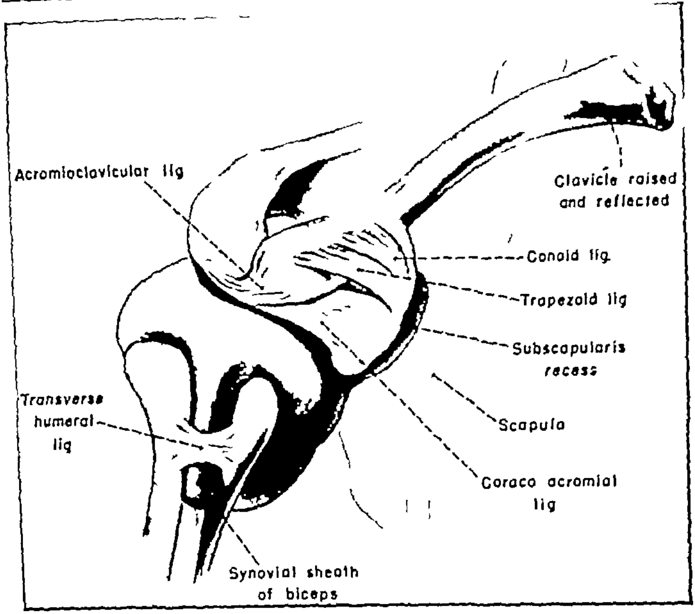

FIG 16 Extensions of the synovial capsule of the scapulohumeral joint and the coracoclavicular ligaments. Note the prolongation of the synovialis anteriorly under the coracoid process, forming the subscapularis recess and the second prolongation lining the bicipital groove it ends as a blind pouch and then is reflected over the biceps tendon.

feriorly it arises from the capsular border of the labrum glenoidale and the bone immediately adjacent to it Anteriorly, its mode of origin depends upon the presence or absence and the size of the synovial recesses so commonly encountered in this region When synovial recesses are present the capsule arises from the anterior neck of the scapula at varying distances from its articular surface It becomes obvious, therefore that the presence and the size of the synovial recesses are determined by the distance from the articular surface of the scapula that the fibrous capsule arises from the anterior neck of the scapula (Detailed anatomy of this region is discussed in Chapter 3) In shoulder joints without synovial recesses the fibrous capsule arises from the entire circumference of the capsular border of the labrum glenoidale the rim of the glenoid cavity and the bone surrounding it.

Distally the fibrous capsule inserts superiorly into the upper portion of the anatomic neck and inferiorly into the periosteum of the humeral shaft at a considerable distance from the margin of the articular cartilage of the humeral head. The fibrous capsule is lined throughout by syno-

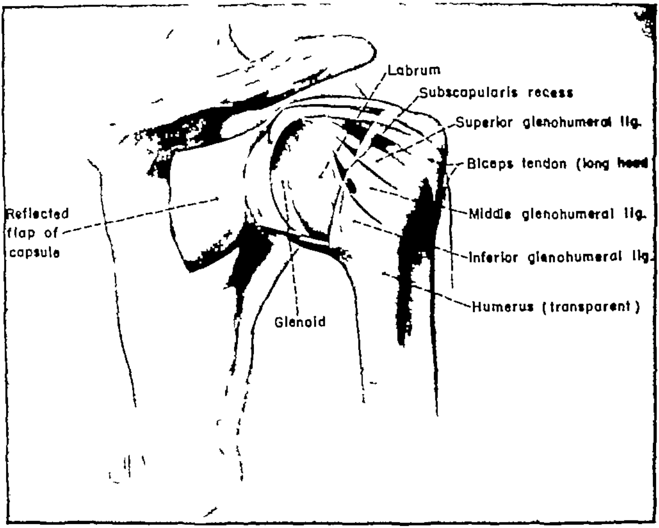

FIG 17 Interior of right shoulder joint, posterior view the posterior portion of the capsule has been reflected medially Observe the arrangement of the three glenohumeral ligaments reinforcing the anterior aspect of the fibrous capsule. They are all directed toward the superior aspect of the glenoid fossa in this instance they all blend with the labrum glenoidale (not the case in all shoulders) Note the direct communication of the subscapularis recess with the inside of the joint cavity In this joint the subscapularis recess communicates with the joint cavity both above and below the middle glenohumeral ligament.

vial membrane that is reflected inferiorly along the anatomic neck of the humerus toward the periphery of the articular cartilage of the humeral head blending with the hyaline cartilage of the head Proximally it extends for varying distances over the labrum glenoidale and blends with its superficial fibers but fails to reach the articular cartilage of the glenoid cavity

In the anterior region of the joint the synovial membrane is loose and redundant It is prolonged (in 81.8 per cent of the shoulders) along the anterior surface of the neck of the scapula toward the root of the coracoid process for varying distances to form the previously mentioned synovial recesses It is also prolonged distally to line *the bicipital groove and then reflected over* the biceps tendon The articular capsule is loose and redundant in the inferior region of the humeral neck With the arm at the side the capsule forms a large nictitating fold in this region As the arm is abducted this fold becomes smaller and disappears when full abduction is attained (Fig 16)

On all sides except the inferior portion,

the fibrous capsule is strengthened by the broad flat tendons of the rotator muscles (supraspinatus, infraspinatus teres minor and subscapularis muscles) These tendons are approximately 2 5 centimeters long humeral head—the coracohumeral ligament and the musculotendinous cuff The latter is not a true ligament but functionally it must be considered as such Although the coracoclavicular ligaments are not related to a

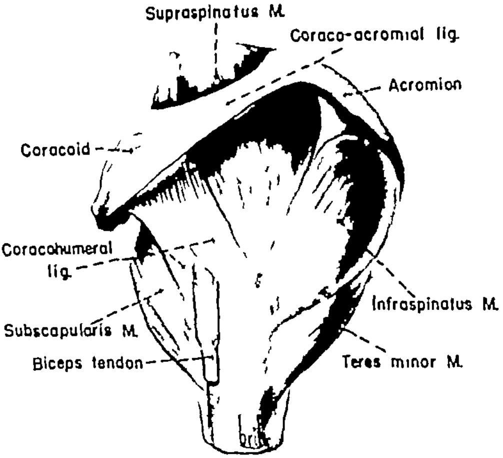

FIG 18 Subdeltoid region of the left shoulder Observe the coracohumeral ligament extending from the outer border of the horizontal limb of the coracoid process to both tuberosities bridging the inter tubercular sulcus also the triangular coraco-acromial ligament and the compactness of the rotator muscles which fuse with the fibrous capsule forming the musculotendinous cuff before they insert into the superior portion of the anatomic neck of the humerus. Note that the lower fibers of the subscapularis muscle anteriorly and the infra spinatus muscle and the teres minor posteriorly insert directly into the shaft of the humerus.

They blend with the fibrous capsule to form the musculotendinous cuff also referred to as the fibrotendinous cuff or the capsulotendinous cuff

LIGAMENTS OF THE SHOULDER JOINT

About the shoulder are demonstrable ligamentous structures which are designed for different functions Notably are those that provide a suspensory apparatus for the joint their integrity ensures stability of the shoulder girdle The coraco-acromial ligament is concerned primarily with motion at the glenohumeral joint

Coracohumeral Ligament

This ligament originates in the outer border of the horizontal limb of the coracoid process passes forward and downward in the interval between the supraspinatus and the subscapularis muscles Here its

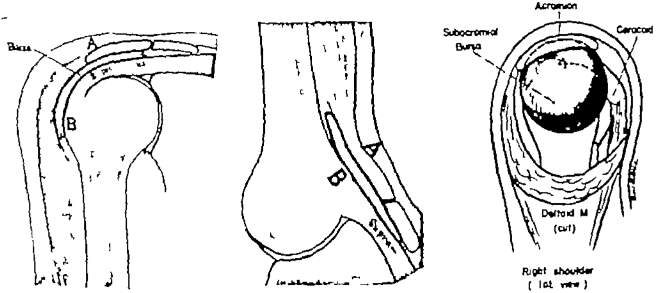

FIG 19 (*Left* and *Center*) Coronal sections through the right shoulder Observe that the roof of the bursa comprises the acromion process and the subdeltoid fascia and its base overlies the tuberosity and the supraspinatus tendon (*Center*) The position of the bursa is depicted with the arm elevated, note that the greater tuberosity has passed beneath the acromion and point B has passed to point A (Codman The Shoulder, p 25) (*Right*) Superolateral view of the right shoulder with the deltoid removed note the spherical shape of the bursa and its extension under the acromion and inward toward the coracoid process. Occasionally it extends beneath the coracoid process.

fibers interlace with those of the fibrous capsule and insert with the capsule into both tuberosities bridging the bicipital groove In this position it acts as a suspensory ligament of the humeral head Its most proximal fibers are so arranged that they unwind and elongate upon external rotation of the shaft of the humerus functioning as a checkrein to external rotation The ligament shortens upon internal rotation (Fig 18) This fiber arrangement is significant in the frozen shoulder In this lesion as the result of a diffuse inflammatory process the fibers become fixed in the shortened position and help freeze the head in a position of internal rotation

Occasionally, the ligament is continuous with the tendon of the pectoralis minor running between the two limbs of the coraco-acromial to reach the fibrous capsule of the glenohumeral joint.

Musculotendinous Cuff

All four short rotator muscles comprise this structure (supraspinatus infraspinatus teres minor and subscapularis muscles) The muscles end in broad flat tendons whose fibers fuse with those of the fibrous capsule So complete is the interlacing of tendon and capsular fibers that it is impossible to separate the two structures by sharp dissection Microscopic examination of the distal one-half to three-quarters inches of the musculotendinous cuff fails to distinguish between the tendinous and capsular components of the cuff which inserts into the upper one-half of the anatomic neck of the humerus completely filling the sulcus In this position it is apparent that this structure functions as a suspensory ligament for the humeral head (Fig 18)

Coraco-acromial Ligament

This triangular structure forms a strong arch across the coracoid and the acromion. It arises with a wide base from the outer edge of the coracoid and tapers to a narrow band to insert into the inner border of the acromion just in front of the acromioclavicular joint Its central fibers are very thin

and often wanting, forming essentially two strong limbs, an anterior and a posterior limb which join at their point of insertion into the acromion (Fig 18)

Considerable significance is attached to the coraco-acromial structure. It separates the subacromial bursa from the acromioclavicular joint, and its under surface forms the roof of the posterior part of the above bursa. In elevating the limb, the tuberosities pass beneath the arch. Codman believed that in elevating the arm this structure guided the head of the humerus and prevented it from gaining a fulcrum on the acromioclavicular joint. On the contrary, however, it has been demonstrated that the integrity of this structure may be sacrificed with impunity without noticeable effect on the functional mechanism of the joint provided that the muscular apparatus is intact. The ligament or segments of it are routinely severed or removed without unfavorable sequelae.

The coraco-acromial arch with the underlying subacromial bursa and loose areolar tissue provides a gliding mechanism between the deep and the superficial muscle strata. Thus it becomes clear why lesions disturbing this mechanism or impingement of the tuberosities or a hypertrophied subacromial bursa against the coraco-acromial arch interfere with the smooth rhythmic elevation of the arm. Such lesions are discussed in their appropriate chapters.

All other ligaments about the shoulder have been described in the discussion pertaining to their respective joints. The glenohumeral ligaments and labrum glenoidale are taken up in Chapter 3 Variational Anatomy and Degenerative Lesions of the Shoulder Joint.

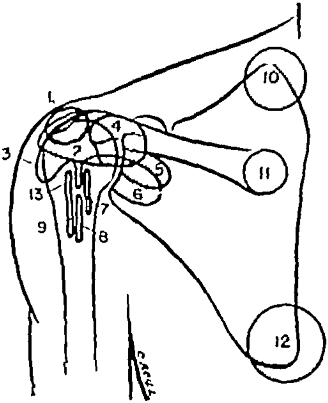

Fig 20 Normal bursae of the shoulder joint (1) subcutanea acromialis (2) subacromial bursa (3) subdeltoid bursa (4) subcoracoid bursa (5) bursa of infraspinatus muscle (6) subscapular bursa, (7) bursa of latissimus dorsi, (8) bursa of teres major. Note 2, 3 and 4 are essentially one bursa; occasionally they may be separated by thin movable film of tissue. 5, 6 and 13 are prolongations of the synovial capsule (13 lines the bicipital groove). 9, 10, 11 and 12 are inconstant and have no official anatomic names. (Redrawn from Codman The Shoulder, p 29)

BURSAE AROUND THE SHOULDER JOINT

Subacromial Bursa and Subcoracoid Bursa (Fig 19)

The complex arrangement of the muscles which overlay the scapulohumeral joint comprise two muscular sleeves: an inner sleeve made up of the short rotator muscles and an outer sleeve of the deltoid and the teres major muscles. These muscular sleeves operate one within the other—a performance made possible by an efficient gliding mechanism between the two strata. Fine filmy, areolar tissue and the subacromial bursa constitute the gliding mechanism. So efficiently does this arrangement function that often it is referred to as a secondary scapulohumeral joint.

The subacromial bursa adheres firmly by its base to the upper and outer portions of the greater tuberosity and to the outer surface of the musculotendinous cuff. Its roof is adherent to the under surface of the

acromion and to the under surface of the coraco-acromial ligament Its lateral walls are prolonged loosely downward under the deltoid muscle, backward and outward under the acromion and mesially under the coracoid process

Therefore as Codman pointed out it is apparent that the bursa in the subcoracoid area is part of the subacromial bursa. The subacromial bursa communicates with the joint cavity only if a tear involving the complete thickness of the musculotendinous cuff opens into the floor of the bursa

The other important bursal structures the subscapularis bursae (recesses) and the infraspinatus bursae (which really are extensions or diverticulae of the glenohumeral joint cavity beneath the respective tendons) are discussed in detail in Chapter 3

Numerous other bursae of lesser significance have been described about the shoulder region and may be listed as follows (Fig 20)

1 Bursae beneath tendons near their insertion into the humerus on either side of the bicipital groove as seen under the pectoralis major, the latissimus dorsi and the teres major muscles

2 Supracoracoid bursa—most likely to be found when there is an anomalous insertion of the pectoralis minor into the coracoid process

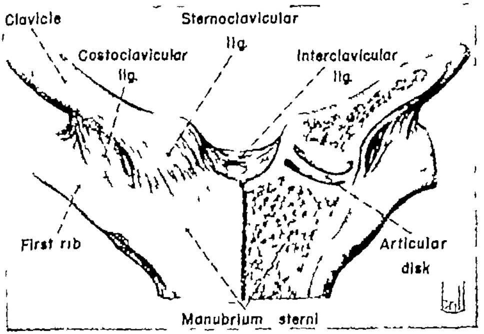

FIG 21 Coronal section of the left sternoclavicular joint. Observe that the joint is divided into two compartments by the fibrocartilaginous disk. The articular end of the clavicle and the sternum are covered by fibrocartilage instead of hyaline cartilage. The interclavicular and the costoclavicular ligaments add to the stability of the joint. (Redrawn from S W Spalteholz Hand Atlas of Human Anatomy Philadelphia, Lippincott)

3 Infraserratus bursa—located between the inferior angle of the scapula and the thoracic wall (Terillon)

4 Subscapular bursa—situated between the upper anterior region of the scapula and the upper three ribs (Goldthwait)

The last two bursae have been credited with being responsible for painful crepitation in the posterior region of the shoulder when the scapula is in motion particularly during such elevation of this bone as shrugging the shoulder

5 Supra-acromial bursa (subcutanea acromialis) situated between the skin and the

dorsum of the acromion, with its base fixed to the acromion

6 Bursa between insertion of the trapezius and the dorsum of the base of the spine

STERNOCLAVICULAR JOINT

This joint is formed by the mesial end of the clavicle and the facet on the posterolateral surface of the manubrium sterni It is the only articulation between the trunk and the upper extremity The configuration of the articulating surfaces of the clavicle and the sternum provides no stability to the joint its integrity depends solely on the surrounding capsule, ligaments and articular disk

The joint cavity is divided into two separate compartments by a fibrocartilaginous disk whose periphery is thicker than its center Directed upward and outward the articular disk anchors the clavicle to the first rib by strong fibers which connect its upper border to the clavicle and its lower border to the first costal cartilage This articular disk plays a very significant role in the mechanism of the shoulder It acts as a shock absorber, protecting the sternum from the full impact of forces directed toward the trunk through the upper extremity

The articular surfaces of the joint are surrounded by an articular capsule which is attached also to the edges of the interarticular fibrocartilage Both anterior and posterior surfaces of the fibrous capsule are reinforced by strong fibrous bands running upward and outward constituting the anterior and posterior sternoclavicular ligaments.

Further stability to the joint is provided by the interclavicular and the costoclavicular or rhomboid ligaments Fibers of the interclavicular ligament run from the top of one clavicle to the other and fuse with the capsular fibers of the joint It is strong yet allows considerable range of motion of the clavicles The strong spiral fibers of the costoclavicular ligament which unwind when the shoulder is brought upward and backward run upward and outward between the first costal cartilage and the proximal end of the clavicle (outside of the sternoclavicular joint)

Modern concepts of mechanism of shoulder movement emphasize the important role contributed by the sternoclavicular joint Also as will be demonstrated the integrity of the articulation must be maintained to attain complete shoulder movement Its obliteration results in definite impairment of shoulder function

ACROMIOCLAVICULAR JOINT

The lateral end of the clavicle demonstrates a shallow surface directed downward and outward, superimposed on the flattened elongated facet of the acromion to form the acromioclavicular articulation While occasionally in a sagittal plane the joint is usually in an oblique plane This arrangement permits upward displacement of the clavicle end when the stabilizing ligaments of the joint are disrupted It is obvious that the articular surfaces favor instability rather than stability of the articulation, whose integrity is maintained entirely by the weak capsular ligaments and the strong coracoclavicular ligaments (trapezoid and conoid ligaments) (Fig 16)

Occasionally a rudimentary interarticular wedge-shaped disk is present with its base attached to the superior portion of the articular fibrous capsule In most instances it divides only the upper half of the joint cavity rarely does it extend the entire width Integrity of the joint is provided chiefly by the coracoclavicular ligaments which arise from the coracoid process are continuous posteriorly and diverge anteriorly to form the outer trapezoid and inner conoid ligaments They are directed upward and backward to insert into the clavicle

Although the above structures firmly anchor the clavicle to the coracoid process their fibers are so arranged that a relative lengthening of the ligaments occurs when the clavicle is rotated on its long axis This

anatomic arrangement makes possible 20° of the total range of upper extremity abduction at the acromioclavicular joint.

TERMINOLOGY OF MOVEMENTS AT SHOULDER JOINT

It is necessary to adopt a group of terms which will best express the numerous movements of the extremity made possible by joint because it occupies a unique position in relation to the planes of the body Also all of its movements are summations of movements occurring simultaneously in all its component joints Figure 22 depicts the anatomic planes through or in relation to which the upper extremity moves at the shoulder joint It must be understood that in all movements of the extremity all

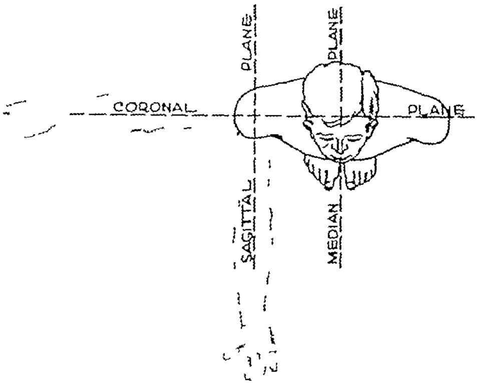

Fig 22 Planes through or in relation to which the arm moves at the shoulder joint (Codman The Shoulder p 40)

the components of the shoulder joint mechanism before one can comprehend the complexity of motion at the shoulder joint That failure to standardize the terminology has led to much confusion is very evident by the literature on movements of the shoulder

Codman was the first to try to unravel this entanglement he evolved a most practical group of terms to designate the movements of the shoulder Moreover he made many pertinent clinical observations referable to the mechanism of the shoulder which will be recorded in this section

Terms expressing the position of the distal segment of a joint such as the knee or the elbow are not applicable to the shoulder four joints (scapulohumeral scapulothoracic sternoclavicular and acromioclavicular joints) of the shoulder unit participate synchronously

ANATOMIC POSITION OF THE EXTREMITY

In man the position of standing with the arms at the side and the palms directed forward is designated the anatomic position (Fig 23)

Elevation

The arm pointing directly upward is designated elevation" It may be attained by bringing the arm up in the coronal plane

in the sagittal plane or in a plane midway between the two

ABDUCTION

Elevation in the coronal plane is called abduction ' To achieve complete elevation in the coronal plane, the arm must be rotated externally If the arm is fully rotated internally and then raised in the coronal plane it will lock below the horizontal position Elevation to the vertical position can be attained only if the arm is first rotated externally 90° Locking at the horizontal position is brought about by impingement of the tuberosities against the acromion process by external rotation of the arm the tuberosities are placed so as to pass beneath the acromion when the arm is elevated to 180°

FORWARD FLEXION

Elevation of the extremity in the sagittal plane is termed "forward flexion" This position is only possible when the arm is rotated internally Forward flexion in man is the equivalent of extension in the quadruped From the anatomic position, if the arm is elevated in the sagittal plane, it will lock about 45° above the horizontal Here further external rotation is nihil by internally rotating the arm 45° it can now be raised to complete elevation

PIVOTAL POSITION

Regardless of what plane the arm ascends to reach complete elevation the ultimate position of the humeral head in relation to the glenoid cavity the coracoid process and the acromion process is the same Codman designated this the pivotal position.' In this position no rotation is possible, either internally or externally A fracture a dislocation or both will occur if the humerus is forced beyond the fixed position

With the arm at the side in the anatomic position and the elbow flexed, the condyles of the lower end of the humerus are in the transverse plane In this position the arm can be rotated internally 90° and externally

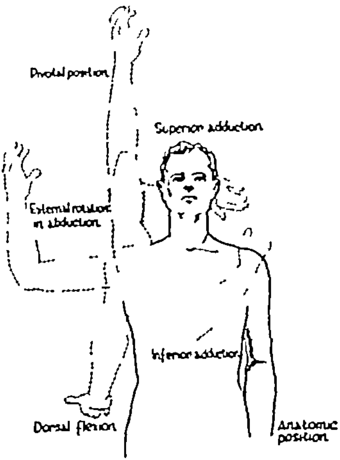

FIG 23 Different positions of the arm and their designations (Codman The Shoulder p 41)

approximately 90°, a total range of roughly 180° As the arm is elevated, regardless of the plane of ascent, the range of rotation gradually diminishes until the arm reaches the pivotal position Here the internal condyle of the humerus points forward and no rotation is possible

During elevation, the arm will lock at levels, depending upon the degree of rotation of the humerus If rotation in the right plane is not hindered elevation is completed in a smooth rhythmical fashion However, if rotation of the humerus in the correct plane is obstructed and the arm is forced beyond the locked position dislocation or fracture of the humeral head results

It is essential to understand these characteristics of the shoulder mechanism to comprehend the basic principles underlying the mechanism of dislocation and fractures of the head of the humerus

Dorsal Flexion

From the anatomic position the arm is brought backward so that the elbow is posterior to the body

Adduction

Superior adduction" is that position in which the elbow is brought toward the median plane above the level of the shoulders

Inferior adduction —the elbow is below the level of the shoulder and is brought toward the median plane.

Adduction is a position midway between superior and inferior adduction

SCAPULOHUMERAL RHYTHM

Elevation of the arm in a smooth continuous rhythmical motion from beginning *to end in which the scapulohumeral scapulo* thoracic sternoclavicular and acromioclavicular joints participate was designated scapulohumeral rhythm by Codman This uninterrupted smooth motion is of great clinical significance because any alteration in the symmetry of the movement is indicative of some such pathologic disorder as lesions of the musculotendinous cuff calcareous tendinitis frozen shoulder etc

MOTION AT THE SHOULDER JOINT

The prevailing concepts on movements at the shoulder must be revised in the light of the work of Inman Saunders and Abbott on the functional mechanism of the shoulder joint These workers carried still further the observations of Codman They broke down the movements of the shoulder joint into successive phases and established the sequence and the component of the shoulder joint responsible for each phase Moreover they evolved a new fundamental principle in shoulder mechanism the muscle force couple This necessitates a revision of the present-day methods or designing new ones to relieve paralytic disorders about the shoulder region (The observations made by the above investigators are recorded in the subsequent section)

The concept is fallacious—that in abduction of the arm the first 90° occurs in the glenohumeral joint and the next 90 in the scapulothoracic articulation (rotation of the scapula on the chest wall) Elevation of the extremity in flexion and abduction is the result of synchronous and continuous motion of all the elements of the shoulder joint complex. Four elements or components constitute this complex (1) the glenohumeral, (2) the sternoclavicular (3) the *acromioclavicular and (4) the scapulothoracic* joints.

Glenohumeral Joint Motion

Elevation of the arm in the coronal (abduction) or in the sagittal plane (forward flexion) is produced by simultaneous motion in both the glenohumeral and the scapulothoracic articulations. During the first 30° of abduction and 60° of flexion, the scapula finds a position of stability in relation to the humerus This is attained either by the scapula's remaining fixed (all motion occurring in the glenohumeral joint until the position of stabilization is reached) or shifting laterally or medially or even oscillating until it is fixed by the humerus *This irregular preliminary period was designated the setting-stage*

From this point the ratio of motion in the two joints is constant until full elevation is complete the ratio is two humeral and one scapular 10° occurring at the glenohumeral and 5° at the scapulothoracic articulation for every 15° of motion. The total scapular motion is 60° and the glenohumeral 120° Also it was demonstrated that motion may occur independently in the above joints By fixation of the scapula the arm can be abducted to 90° passively and 120 actively Loss of scapular motion *however decreases the power of abduction* by a third

The clavicle plays a significant role in elevation of the arm Any interference with normal motion at either end of the clavicle

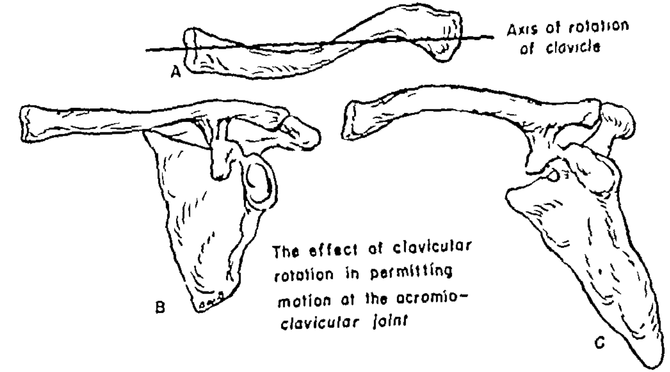

FIG 24 The clavicle rotates on its long axis like a "crankshaft" this is made possible by the configuration of the clavicle whose outer third is curved, producing a relative lengthening of the coracoclavicular ligament *when the clavicle rotates on its* long axis. (Redrawn from Inman Saunders and Abbott J Bone & Joint Surg 26 2)

is reflected in the total range of elevation Normal scapular rotation on the chest wall is dependent *upon unrestricted motion* at the sternoclavicular and the acromioclavicular joints

Sternoclavicular Joint Motion

This joint permits 40 elevation of the clavicle during elevation of the arm, the *ratio being* 4 elevation of the clavicle for every 10° elevation *of the arm* The range of clavicular elevation is expended *during* the first 90° elevation of the arm

Acromioclavicular Joint Motion

In this joint 20° of motion occurs Motion occurs in two different phases of elevation part of it takes place in the first 30° and the remainder after 135° elevation has been attained The clavicle is bound firmly to the coracoid process and the *acromion by the* coracoclavicular ligaments Motion of this joint is made possible only by the configuration of the clavicle Its outer one-third is curved so that a relative lengthening of the coracoclavicular ligaments occurs upon rotation on its long axis *thereby allowing* a certain range of free motion at this joint

The clavicle really acts like a "crank shaft" (Fig 24) The amount of motion *occurring in* both the sternoclavicular and the acromioclavicular *joints is equivalent* to the amount of scapular rotation on the chest wall (60°)

Practical Significance of Above Observations

It becomes apparent that obliteration of *motion* at either end of the clavicle surgically *or by disease* results in restriction of arm elevation equal to the amount of motion lost in the affected joints Therefore reconstructive surgical procedures should aim to preserve or restore motion in the sternoclavicular and the acromioclavicular articulations Arthrodesing procedures of these joints or their equivalents are never

justified On the other hand excision of the outer end of the clavicle, combined with arthrodesis of the glenohumeral joint, may be a valuable step to increase the range of abduction (Inman, Saunders and Abbott)

MECHANICAL FORCE REQUIREMENTS FOR MOTION AT THE SHOULDER JOINT

The meticulous work of the aforementioned observers disclosed, furthermore, that equilibrium at the glenohumeral joint, regardless of the position of the arm, was the result of three forces (1) the weight of the extremity, acting at its center of gravity, (2) muscular masses responsible for abduction (chiefly the deltoid) and (3) the resultant of the above two forces which acts through a center of rotation but in an opposite direction to that of the deltoid

The third force in turn, is the resultant of two other components namely, (1) a passive component, the friction and the pressure of humeral head against the

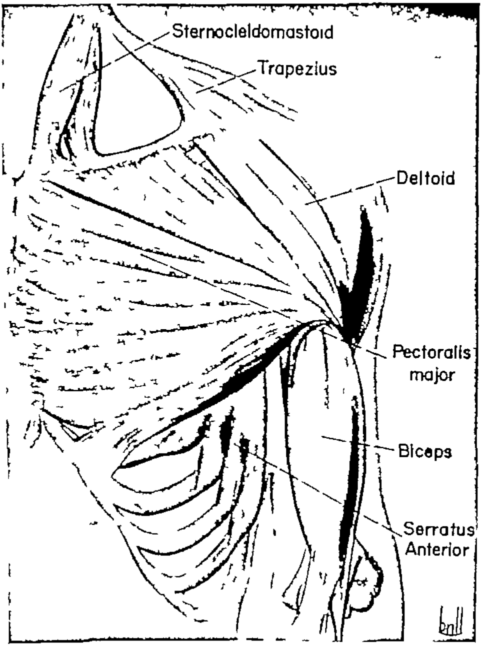

FIG 25 Outer muscles of the anterior region of the shoulder

glenoid cavity and (2) the active component, the downward pull of the infraspinous muscles (the infraspinatus, the teres minor and the subscapularis muscles) This last force is represented by a force acting at right angles to the plane of the glenoid cavity and the other parallel to the axillary border of the scapula

The force of elevation (pull of the deltoid) together with the active component of the third force (downward pull of the infraspinous muscles) establishes the mus-

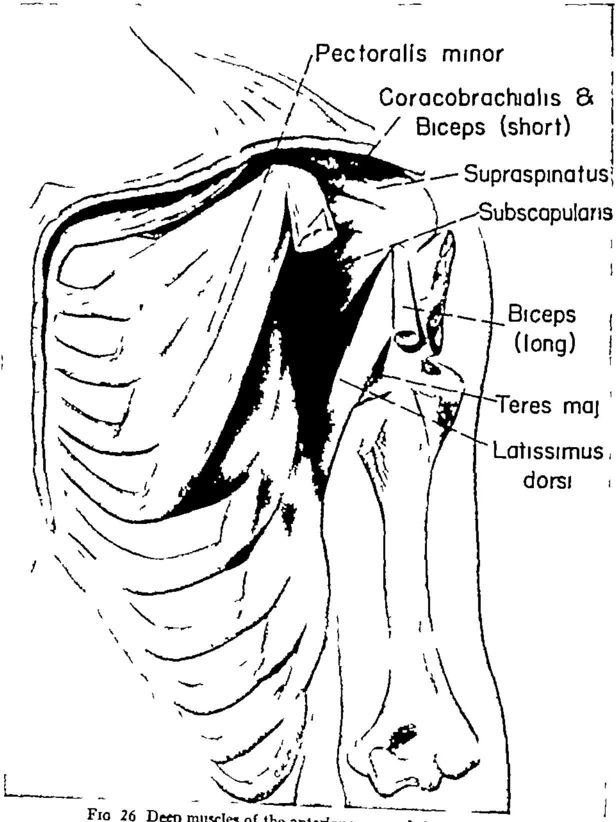

FIG 26 Deep muscles of the anterior region of the shoulder

cle force couple" necessary for elevation of the limb It was observed that the magni tude of the force required to bring the limb to 90° elevation was at this point, 8.2 times the weight of the extremity Past 90° the force requirements decreased progressively, reaching zero at 180 The force require ments of the lower component of the muscle force couple (downward pull of the infraspinous muscles) attained its maxi mum at 60 , at which point the force re quirements were 9 6 times the weight of the limb Past 90° a progressive decrease of the magnitude of the force was noted reaching zero at 135°

The same basic principle of the muscle force couple operates in scapular rotation Three forces are responsible for rotation of the scapula on the chest wall during eleva tion of the extremity (1) force which supports the weight of the shoulder girdle operating in a vertical and upward direc tion (2) force acting on the acromion in a medial direction and (3) force acting on the inferior angle of the scapula (serratus anterior muscle)

The force operating from the region of the acromion is a resultant of a passive com ponent represented by the resistance of the clavicle and an active component the upper portion of the trapezius which here assumes a dual function by aiding in the support of the shoulder girdle

The second and the third forces establish the muscle force couple essential for rota tion of the scapula they operate in opposite directions and are of equal magnitude reaching their maximum at 90 elevation then dropping progressively to zero at 180

Some very significant characteristics are exhibited by the trapezius muscle At rest its function is entirely supportive during the early phase of elevation of the arm from zero to 35° because of the shift in the angle of action of the muscle it assumes a dual function supportive and rotatory Beyond 35° to 140 its rotatory efficiency progressively increases reaching its maximum at 90° Beyond 140° its supportive efficiency steadily increases while its rotatory decreases

Experiments conducted by Inman, Saunders and Abbott on muscle activity dur ing motion in living subjects have un covered observations of great significance and importance relative to the mechanism of the shoulder joint. As a result of these studies muscles participating in shoulder motion were grouped into functional units or groups

Abductor and Flexors of the Humerus

This group comprises (1) deltoid, (2) pectoralis major and (3) supraspinatus muscles, all three act as a single functional unit in abduction and flexion of the arm. The sum of the action currents of the indi vidual muscles of this group produces a smooth, regular curve in both flexion and abduction The curve of flexion reaches its summit at 110° the curve of abduction at 90°, the former is of slightly greater amplitude.

Deltoid In abduction the total potential of this muscle is of greater amplitude than that demonstrated in flexion

Pectoralis Major Various portions of *this muscle exhibit differences in activity* depending upon the character of the motion executed In abduction no activity is de monstrable in any portion of the pectoralis major In flexion the clavicular portion of the muscle is most active acting synchronously with the deltoid Some activity but to a lesser degree is also discernible in the manubrial fibers of the sternocostal head The remaining fibers of the pectoralis major disclose no cavity in flexion or abduction.

Supraspinatus. The *most significant fea* ture of the supraspinatus is that it operates synchronously and simultaneously with the deltoid in all phases of abduction and flexion Codman made this observation but failed to demonstrate it experimentally as the above workers have so clearly done. This observation dispels the old concept that the supraspinatus muscle initiated ab-

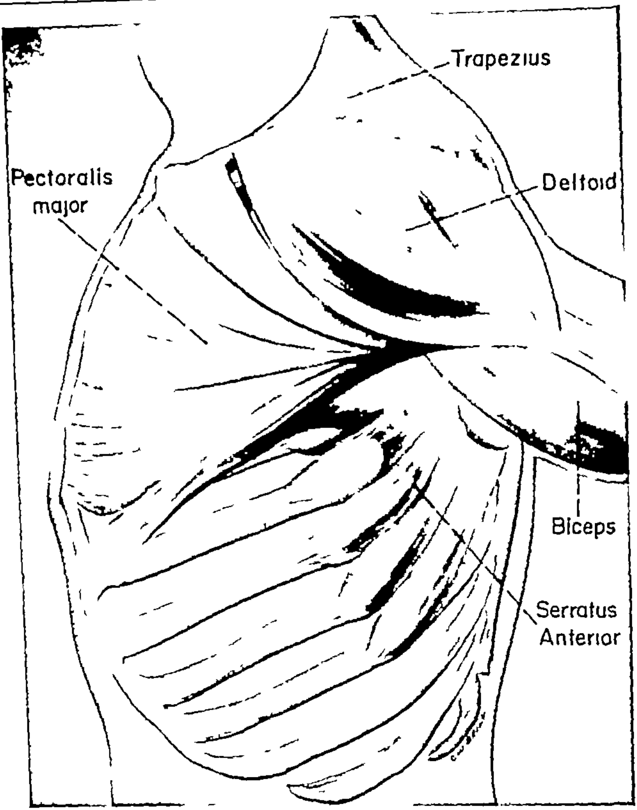

FIG 27 Outer muscles of lateral region of the shoulder

duction and thereafter the movement was completed by the deltoid muscle

Depressors of the Humerus

The infraspinous muscles comprise this unit, including the subscapularis the infra spinatus and the teres minor muscles As previously indicated, this functional unit constitutes the inferior component of the muscle force couple during flexion and abduction of the extremity All three elements function simultaneously throughout the en tire arcs of motion

Despite the fact that the teres minor

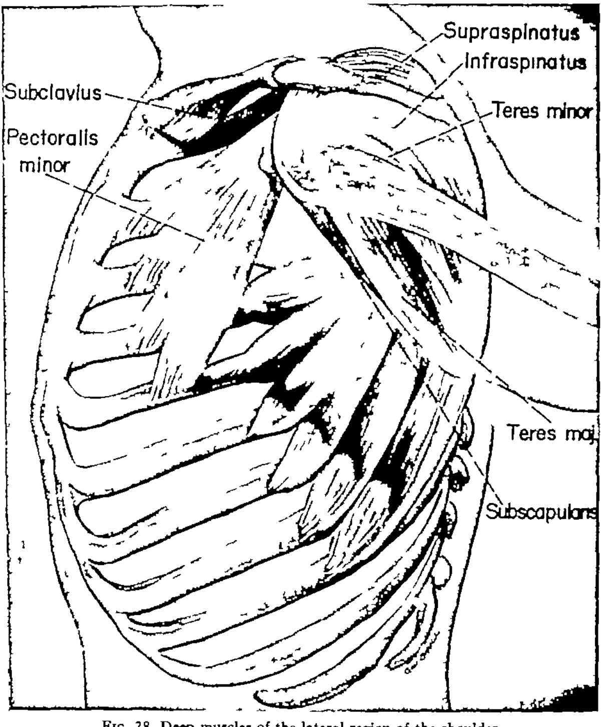

Fig 28 Deep muscles of the lateral region of the shoulder

from a morphologic viewpoint originally was part of the deltoid muscle it behaves in a fashion similar to the infraspinatus throughout its various phases of activity both in flexion and abduction of the extremity

Scapular Rotators

This important functional group comprises the trapezius the serratus anterior and the levator scapulae muscles Various portions of the trapezius and the serratus anterior perform different functions The upper component of the muscle force couple is required for rotation of the scapula and consists of the upper portion of the trapezius the levator scapulae and upper digitations of the serratus anterior All three elements operate as a single unit with two functions besides being the upper compo-

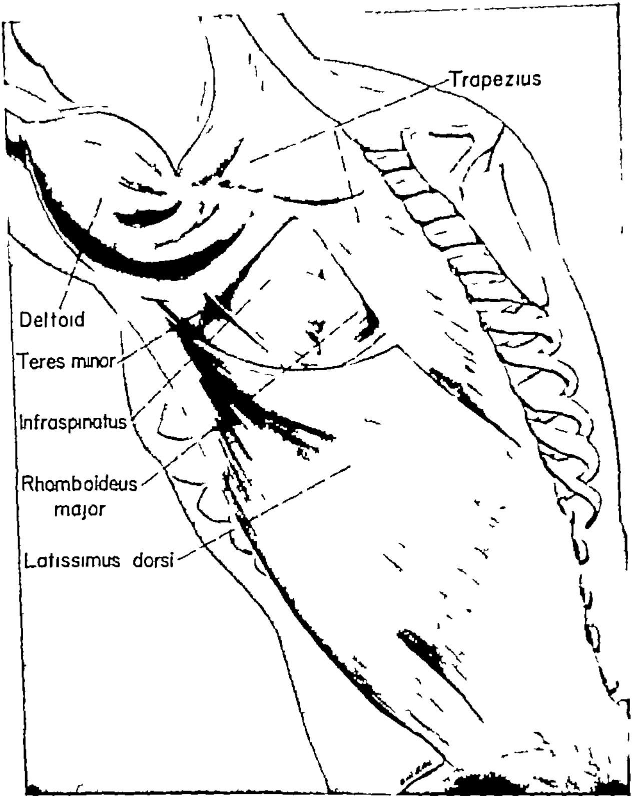

FIG 29 Outer muscles of the posterolateral region of the shoulder

nent of the force couple necessary for scapular rotation The unit supports passively the shoulder girdle and also elevates it.

The inferior component of the force couple consists of the lower portions of the trapezius and the lower digitations of the serratus anterior Both act continuously in a similar fashion except that in abduction the lower trapezius is more active than in flexion, during which movement it relaxes in order to permit the scapula to slip forward At this phase of flexion the serratus anterior (lower digitations) assumes the predominant role of the lower force couple

The middle portion of the trapezius and the rhomboids act as stabilizers of the scap-

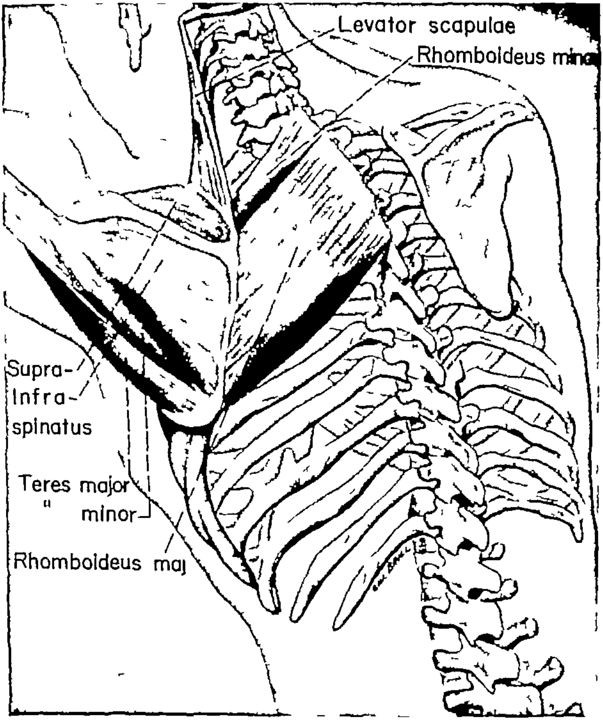

FIG 30 Deep muscles of the posterolateral region of the shoulder

ula during abduction relaxing in flexion to permit rotation of the scapula on the thorax.

It was interesting to note the role of the teres major muscle in the functional mechanics of the shoulder joint. It discloses no evidence of any activity during motion activity is demonstrable only when maintenance of a static position is required

PRACTICAL SIGNIFICANCE OF MUSCLE FORCE COUPLE PRINCIPLE

In the light of the aforementioned observations it is obvious that free complete motion at the shoulder joint can be achieved only when efficient force couples (as de

scribed for glenohumeral motion and scapular rotation) are functioning Therefore, as pointed out by Inman Saunders and Abbott, all reconstructive procedures about the shoulder aiming to restore motion in paralytic disorders of this region must re establish the force couple mechanism which insists on rearrangement rather than substitution of muscles The belief that power in the deltoid assures abduction of the arm must be discarded

Regardless of the magnitude of deltoid activity, abduction cannot be achieved without an efficient inferior component of the force couple acting on the humeral head (depressing action of the infraspinatus muscles) This essential component may be restored by transplantation of the latissimus dorsi and the teres major to the postero-inferior surface of the greater tuberosity If these muscles are paralyzed, some stabilization of the glenohumeral joint may be attained by utilizing the biceps tendon as in the Nicola procedure or one of its modifications

It has been recorded that only the clavicular head of the pectoralis major muscle functions as an elevator of the arm in flexion hence, this portion alone can be utilized as an abductor the remaining portions showing activity only in adduction and medial rotation of the limb Any procedure designed to use the sternocostal elements as abductors is doomed to failure No amount of re-education will result in independent contraction of only a portion of the pectoralis major it always performs as a whole when voluntarily contracted Therefore its sternocostal portion can be utilized as a lateral rotator

According to Inman, Saunders and Abbott the muscles supporting the scapula (the levator scapula the rhomboids and the upper and the middle portions of the trapezius) make it possible for the force couple essential for scapular rotation to operate In paralysis of these supporting muscles the scapula may be stabilized by fascial transplant from the lower cervical spinous process to the base of the spine of the scapula or its upper border (Lowman) thereby re-establishing the fulcrum which is necessary for performance of the force couple

Muscles such as the teres major which demonstrate activity only in static positions, cannot be made to assume active roles during motion of the extremity Therefore the teres major cannot be utilized to replace the infraspinatus group

GLIDING MECHANISM OF BICEPS TENDON

The concept that the biceps tendon moves up and down the groove during motions at the glenohumeral joint must be discarded With the bicipital tendon and groove exposed under local anesthesia, it can be demonstrated on living subjects that the biceps tendon remains fixed in the groove during motion but the head of the humerus glides up and down the tendon Contraction of the biceps muscle by supinating the forearm or flexing the elbow makes the tendon taut but produces no motion of the tendon in the groove All movements at the shoulder joint regardless of the plane in which the arm is elevated are accompanied by gliding motions of the humerus on the tendon

Internal rotation of the arm forces the biceps tendon to perform over the medial wall of the groove the lesser tubercle, from a mechanical viewpoint, functions as a trochlea Such a position forces the tendon to work at a great mechanical disadvantage External rotation of the arm places the tendon over the top and the center of the head of the humerus and on the floor of the groove In this position the mechanical efficiency of the tendon is greatly enhanced and can act as a depressor of the head of the humerus and participate as an abductor of the limb a function it normally performs in lower forms

IMPAIRMENT OF MUSCLE FORCE COUPLE BY ISOLATED NERVE PARALYSIS AND OTHER LESIONS

Impairment of the efficiency of the muscle force couples acting upon the humerus and the scapula by isolated muscle paralysis results in varying degrees of disability, depending upon the muscles involved and the importance of these components in the performance of the force couple Isolated paralysis of the deltoid the infraspinatus and the serratus anterior muscles causes great disability while paralysis of the supraspinatus and the trapezius does not seriously impair the functional mechanism of the shoulder

Deltoid Paralysis

Permanent axillary nerve palsy is followed by pronounced impairment of the upper muscle force couple necessary for abduction and flexion of the extremity The deltoid mass is the most essential component of this force couple Occasionally a few degrees of abduction may be achieved by the supraspinatus and the clavicular head of the pectoralis major muscles

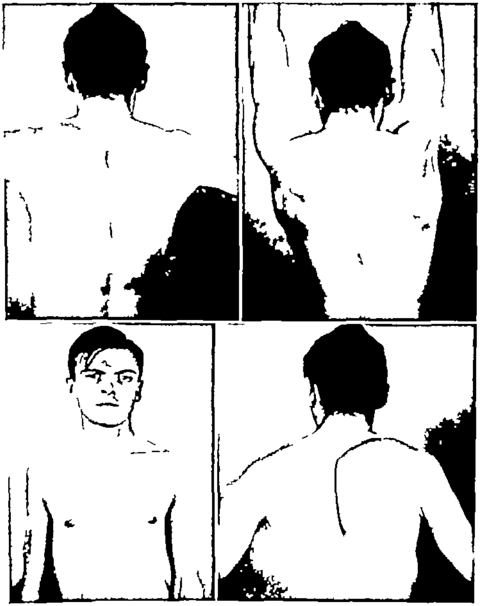

Fig. 31 The ability of an individual with paralysis of the right deltoid muscle to abduct the arm with normal scapulohumeral rhythm and good power

In rare instances, complete abduction is possible in spite of paralysis of the deltoid. Abduction is accomplished by a hypertrophied supraspinatus muscle. One such case has been studied by the author (Fig 31). The patient was able to initiate abduction and carry the movement to completion with normal scapulohumeral rhythm and good power. He participated without difficulty in such athletic activities as baseball and golf. His only complaint was fatigue after an unusually active day. Several such cases have been reported in the literature. Generally, however, the supraspinatus fails to compensate for loss of deltoid power, and the resulting impairment of function is severe.

RUPTURE OF THE SUPRASPINATUS TENDON

Paralysis of the supraspinatus muscle alone is an exceedingly rare lesion; however, rupture of the supraspinatus tendon (a relatively common disorder) is its functional equivalent. For a long time following the work of Codman it was accepted that the supraspinatus muscle occupied a position of great significance in the mechanism of elevation of the extremity. Clinical investigation has re-evaluated the importance of this muscle and has placed it in a position of lesser significance.

Electromyographic studies disclose that the supraspinatus functions simultaneously and continuously with the deltoid muscle and that it is not the initiator of abduction. This observation is confirmed clinically in cases with rupture of the supraspinatus tendon which possess normal scapulohumeral rhythm and abduction power. This point is further emphasized by the investigation conducted on a series of shoulder joints, obtained postmortem from individuals who prior to their death exhibited no clinical disorders of their shoulders (see pp 105-107, Chap 3). Rupture of the supraspinatus tendon was a frequent abnormality in the shoulders of individuals past middle life, yet this lesion gave rise to no demonstrable clinical dysfunction of the extremity.

It becomes clear that the role the supraspinatus muscle plays in the efficiency of the upper muscle force couple designed for elevation and flexion of the limb, is a minor one. Moreover, it is evident that the humerus can attain a fulcrum on the glenoid cavity without an intact supraspinatus tendon.

RUPTURE OF THE MUSCULOTENDINOUS CUFF

It will be shown in (pp 105-107) Chapter 3 that the size of the tear (except in cases of complete avulsion of the cuff) is not the factor that determines the degree of functional impairment in the shoulder. The degree of loss of function depends upon the severity of muscle imbalance between the deltoid muscle and the rotator muscles resulting from rupture of the cuff. Extensive tears may produce no severe impairment of function if the remaining portion of the intact cuff is capable of stabilizing the head of the humerus against the glenoid cavity and balancing the power of the deltoid muscle. If a very powerful deltoid muscle exists, as is found in laborers, a relatively small tear may be sufficient to disturb the above muscle balance sufficiently to cause marked impairment of function.

PARALYSIS OF SERRATUS ANTERIOR

The exposed position of the long thoracic nerve makes it vulnerable to trivial injuries, a condition frequently encountered in young athletic individuals. One case in the author's files resulted from direct pressure on the nerve by an osteochondroma located on the ventral surface of the scapula. Fortunately, most acute lesions are not complete, and recovery is the rule.

Complete lesions result in total impairment of the mechanism of scapular rotation. Both the upper and the lower force couples are affected. The trapezius muscle is unable to compensate for the loss of power of the serratus anterior muscle. Abduction is impaired severely and is accompanied by a shift of the scapula toward the

FIG 32 Incomplete paralysis of the serratus anterior muscle resulting from pressure on the long *thoracic nerve by an osteochondroma* on the ventral surface of the scapula Note the winging of the scapula. Abduction of the arm was not impaired (7 days after removal of a bone tumor)

vertebral column, there is marked winging of the scapula on motion resulting from failure of the serratus anterior to fix the scapula on the chest wall

In incomplete lesions, weak abduction is possible, but winging of the scapula is still a prominent feature Pushing forward against resistances causes pronounced backward displacement of the vertebral border of the scapula, accentuating the winged deformity (Figs. 32 and 33)

PARALYSIS OF TRAPEZIUS

Complete lesions of this muscle also cause serious impairment of the scapular rotatory force couple The scapula is displaced and rotated downward and outward Attempts at abduction, which is only possible to the horizontal or slightly below, accentuates the *deformity while forward flexion diminishes* it (Fig 34) However, cases have been reported in which lesions of the trapezius did not disturb the normal mechanism of the shoulder to any appreciable degree motion

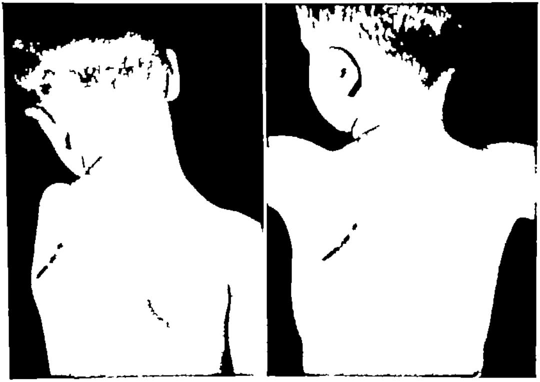

FIG 33 Stability of the scapula restored after recovery of the serratus anterior muscle (6 weeks after operation)

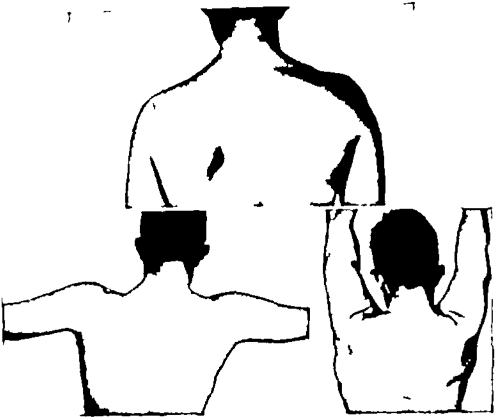

FIG 34 Paralysis of left trapezius muscle, caused by penetrating wound of the right side of the neck (*Top*) Lateral and downward displacement of scapula and flaring of its vertebral border (*Left*) Maximum range of abduction (90°) reveals return of power to the muscle after spontaneous regeneration of the accessory nerve. (*Right*) Complete abduction of the arm is now possible. Time of regeneration was 11 months (Haymaker and Woodhall Peripheral Nerve Injuries, Philadelphia, Saunders)

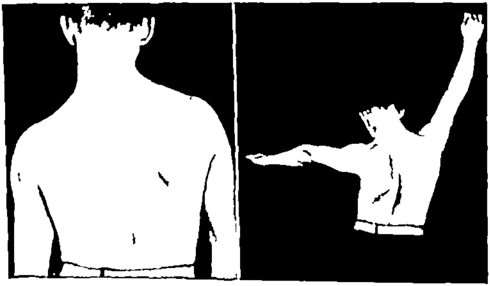

FIG 35 Complete paralysis of left trapezius and serratus anterior muscles caused by penetrating wound implicating the accessory and the long thoracic nerves. At rest the left shoulder droops, and slight flaring of the vertebral border of the scapula is discernible Elevation is possible to 90° only in the forward plane. Observe the pronounced flaring of the inferior angle of the scapula when the above position of elevation is maintained. (Haymaker and Woodhall Peripheral Nerve Injuries Philadelphia Saunders)

Fig 36 Age, 2 months no centers of ossification for the head of the humerus are demonstrable.

in flexion and abduction was rhythmical and powerful Apparently the serratus anterior, in certain instances, can compensate to assume the work of the trapezius in both the upper and the lower force couples

Paralysis of both the trapezius and the serratus anterior results in pronounced dysfunction of the shoulder mechanism. Attempts at elevation produce a very characteristic deformity Some abduction of the humerus occurs at the scapula, but the scapula fails to rotate outward and upward instead, it rotates downward Motion is accompanied by marked winging of the vertebral border and inferior angle of the scapula (Fig 35)

OSSIFICATION OF THE UPPER END OF THE HUMERUS

At birth a small ovoid nucleus for the head of the humerus may be present more frequently this center of ossification does not appear until the fourth or the sixth month (Fig 36) During the second year of life a nucleus for the greater tuberosity ap-

Fig 37 (*Left*) Age 14 months a large nucleus for the head and a smaller one for the greater tuberosity is plainly visible.
Fig 38 (*Right*) Same patient at 2 years of age.


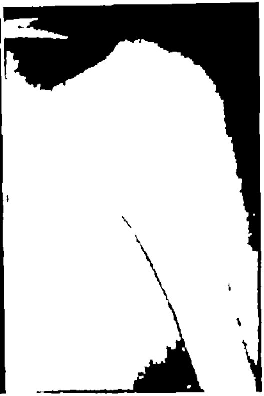

FIG 39 (*Left*) Age 4 to 5 years note the appearance of a third epiphysis which is destined to be the lesser tuberosity
FIG. 40 (*Right*) Age 7 years, greater and lesser tuberosities have fused into one mass. This usually occurs during the fifth year

pears lateral to that for the head (Fig 37 and 38) The epiphysis for the lesser tuber osity appears during the fifth year (Fig 39) it is rarely possible to demonstrate all three centers of ossification on one roent genogram The nuclei for the tuberosities fuse into one mass in the fifth year (Fig 40) which in turn unites with that of the head of the humerus between the twelfth and the fourteenth years (Fig 41) The head unites with the shaft of the humerus during the nineteenth year

FIG 41 Age 12 Epiphysis of the tuberosities has united with that of the head Observe a small nucleus at the end of the coracoid process and one for the end of the acromion The latter appears between 12 and 15 years and usually com prises three or more centers of ossification.

CONGENITAL ABNORMALITIES

CONGENITAL HIGH SCAPULA (SPRENGEL'S DEFORMITY)

This anomaly also referred to as unde scended scapula and elevated scapula, is by far the most frequently encountered con genital deformity of the shoulder girdle In this condition the scapula which arises as a cervical appendage, fails to migrate cau

FIG 42 (*Left*) Age, 17 and 18 years. The epiphyseal plate between the head and the shaft of the humerus is markedly thinned as is the one at the end of the acromion.

FIG 43 (*Right*) Age, 19 Fusion between the head and the shaft of the humerus is completed.

dally, during early fetal development to its normal position on the thorax

Normally the scapula meets the upper portion of the thorax by the end of the third month Occasionally however the scapula

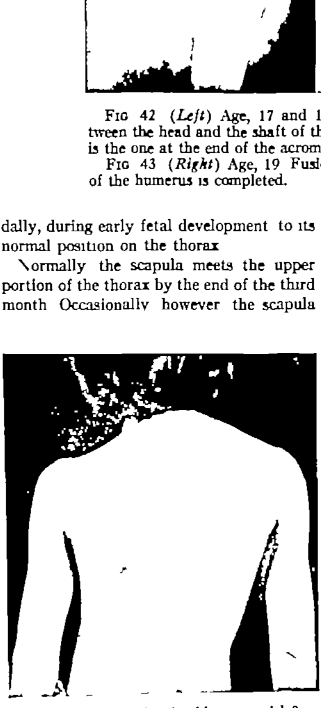

FIG 44 Sprengel s shoulder in a girl 8 years of age.

fails to free itself from the cervical vertebrae and remains attached to the cervical spine by its vertebral border or by a fibrous or bony structure varying in size from a thin strip to a large bony plate the supra capula This extends from the angle formed by the superior and the inferior vertebral borders to the lower cervical or first thoracic spine The scapula may be normal in size and shape or smaller than normal with an altered configuration the breadth being increased and the length decreased. Occasionally the deformity is bilateral. The portion above the spine may be angulated sharply forward to conform to the contour of the upper portions of the thoracic cage

Elevation of the scapula usually is combined with such other congenital anomalies as failure of fusion in the midline of the laminae of some cervical vertebrae cranium bifidum defects in the upper dorsal vertebrae and with such developmental anomalies of the thoracic outlet as cervical ribs and abnormal first thoracic ribs hemivertebrae congenital scoliosis fusion of ribs and irregular vertebral segmentation Developmental defects of the shoulder mus-

culature may exist All or part of the trapezius may be absent, and the levator scapulae and the rhomboidei muscles may exist as strips of fibrous or cartilaginous tissue running from the base of the occiput or spine to the vertebral border of the scapula Torticollis may be a concomitant deformity

When the arm is elevated the scapula fails to shift laterally its lower angle does not rotate outward when the extremity is brought above the horizontal Little or no dysfunction of the shoulder exists in most instances. While slight restriction of elevation of the extremity in the coronal and sagittal plane usually exists, other movements are not affected The over all functional efficiency of the shoulder girdle is good

The undesirable cosmetic appearance of the shoulders rather than dysfunction forces parents to seek medical advice Surgery, in most instances does not yield good results, and one wonders whether the operations performed to correct this deformity are justifiable in the face of so many disappointing results Nevertheless operation may improve slightly the appearance of the patient and increase the range of motion of the scapula on the thorax this is particularly true if performed in the early years of life (rarely before the age of 3) before marked adaptative structural changes have occurred which preclude any correction or increase in function of the extremity

FIG 45 (*Top*) Congenital elevation of the scapula. Observe that the scapula is placed high on the thoracic cage its breadth is increased and its length decreased It is rotated outward and forward on its vertical axis and it possesses a suprascapular bone Note the congenital malformation of the upper thoracic cage and the presence of long cervical ribs. (H Ostrum Philadelphia General Hospital)

FIG 46 (*Bottom*) Congenital elevation of the scapula with an omovertebral bone (H Ostrum)

Operative Technic. The operation most commonly employed to correct congenital high scapula is that of Schrock, or a modification of this procedure Essentially it comprises subperiosteal stripping of the entire scapula displacing it distally as far as possible and fixing it in its new site by suturing its inferior angle to a rib

A long slightly curved skin incision is made parallel to and one inch to the outer side of the vertebral border of the scapula, extending from above the superior angle to below the inferior angle All muscle attachments are divided at the vertebral border and detached subperiosteally The subperiosteal dissection is continued along the ventral surface of the scapula the suprascapular and the infrascapular surfaces the spine (detaching the trapezius) and the upper border of the scapula Care is exer

FIG 42 (*Left*) Age 17 and 18 years. The epiphyseal plate between the head and the shaft of the humerus is markedly thinned, as is the one at the end of the acromion.

FIG 43 (*Right*) Age, 19 Fusion between the head and the shaft of the humerus is completed.

dally, during early fetal development to its normal position on the thorax

Normally, the scapula meets the upper portion of the thorax by the end of the third month Occasionally however the scapula fails to free itself from the cervical vertebrae and remains attached to the cervical spine by its vertebral border or by a fibrous or bony structure, varying in size from a thin strip to a large bony plate the suprascapula. This extends from the angle formed by the superior and the inferior vertebral borders to the lower cervical or first thoracic spine The scapula may be normal in size and shape or smaller than normal with an altered configuration, the breadth being increased and the length decreased. Occasionally the deformity is bilateral. The portion above the spine may be angulated sharply forward to conform to the contour of the upper portions of the thoracic cage

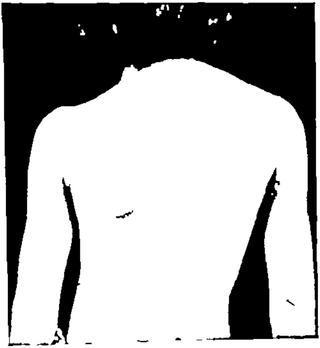

FIG 44 Sprengel s shoulder in a girl 8 years of age.

Elevation of the scapula usually is combined with such other congenital anomalies as failure of fusion in the midline of the laminae of some cervical vertebrae cranium bifidum defects in the upper dorsal vertebrae and with such developmental anomalies of the thoracic outlet as cervical ribs and abnormal first thoracic ribs hemivertebrae congenital scoliosis fusion of ribs and irregular vertebral segmentation Developmental defects of the shoulder mus-

culature may exist All or part of the trapezius may be absent, and the levator scapulae and the rhomboidei muscles may exist as strips of fibrous or cartilaginous tissue running from the base of the occiput or spine to the vertebral border of the scapula Torticollis may be a concomitant deformity

When the arm is elevated the scapula fails to shift laterally its lower angle does not rotate outward when the extremity is brought above the horizontal Little or no dysfunction of the shoulder exists in most instances While slight restriction of elevation of the extremity in the coronal and sagittal plane usually exists other movements are not affected The over all functional efficiency of the shoulder girdle is good

The undesirable cosmetic appearance of the shoulders rather than dysfunction forces parents to seek medical advice Surgery, in most instances does not yield good results and one wonders whether the operations performed to correct this deformity are justifiable in the face of so many disappointing results Nevertheless operation may improve slightly the appearance of the patient and increase the range of motion of the scapula on the thorax this is particularly true if performed in the early years of life (rarely before the age of 3) before marked adaptative structural changes have occurred which preclude any correction or increase in function of the extremity

Operative Technic. The operation most commonly employed to correct congenital high scapula is that of Schrock, or a modification of this procedure Essentially, it comprises subperiosteal stripping of the entire scapula displacing it distally as far as possible and fixing it in its new site by suturing its inferior angle to a rib

A long slightly curved skin incision is made parallel to and one inch to the outer side of the vertebral border of the scapula extending from above the superior angle to below the inferior angle All muscle attachments are divided at the vertebral border and detached subperiosteally The subperiosteal dissection is continued along the ventral surface of the scapula, the supra scapular and the infrascapular surfaces, the spine (detaching the trapezius) and the upper border of the scapula. Care is exer

FIG 45 (*Top*) *Congenital elevation* of the scapula. Observe that the scapula is placed high on the thoracic cage its breadth is increased and its length decreased It is rotated outward and forward on its vertical axis, and it possesses a suprascapular bone Note the congenital *malformation of the upper thoracic* cage and the presence of long cervical ribs. (H Ostrum Philadelphia General Hospital)

FIG 46 (*Bottom*) Congenital elevation of the scapula with an omovertebral bone (H Ostrum)

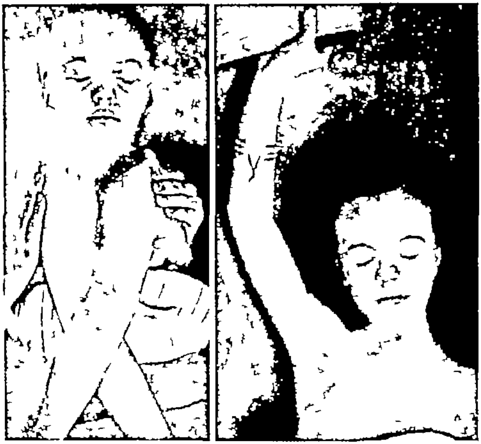

Fig 47 Cleidocranial dysostosis The shoulders are readily approximated in the midline beneath the chin. Shoulder function is not impaired. (Mercer Orthopedic Surgery London Arnold)

Fig 48 Roentgenogram of a case of cleidocranial dysostosis. Absence of clavicles (H Ostrum)

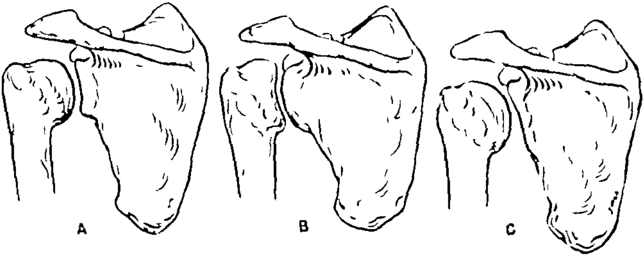

FIG 49 Congenital deformities of scapulohumeral joint (A) Humerus varus (B) Articular surface of the glenoid cavity is convex and that of the humerus concave (C) Shallow flattened glenoid fossa

cised to avoid injuring the suprascapular nerve and the transverse scapular artery as they traverse the suprascapular notch Any fibrous band or osseous bar between the scapula and the vertebral column is excised the prominent upper portion of the scapula may be removed The entire scapula is then displaced caudally as far as possible, and the inferior angle is sutured with stout chromic catgut to a rib to ensure maintenance of its new position

After wound closure the arm is immobilized by a Velpeau dressing or a plaster of Paris swathe (Fig 198) for 4 weeks, this is followed by physiotherapy to restore normal shoulder function If adequate displacement of the scapula cannot be achieved by simple subperiosteal detachment of all soft tissue additional mobilization may be attained by an osteotomy at the base of the acromion

Cleidocranial Dysostosis

This is an exceedingly rare congenital abnormality and hereditary transmission exists in most instances Occasionally however hereditary plays no part The characteristic features are

1 Aplasia of the clavicles
2 Delay in closure of the cranial suture
3 Excessive enlargement of the transverse diameter of the cranium while the base of the skull and the face remains relatively small

Cases have been reported in which other congenital defects existed together with such conditions as achondroplasia, defective development of the small bones of the hands and the feet malformation of the vertebral column the pelvis and the femora and disturbance of normal dentition Bones of both membranous and endochondral derivation may be affected

Varying degrees of aplasia of the clavicles may exist, caused by developmental failures of only a small portion (usually the acromial end) to absence of the entire clavicle There may also be abnormal development of the large shoulder girdle muscles particularly the pectoralis major, the deltoid and the trapezius The clavicular portion of the trapezius and the deltoid muscles may be deficient or absent

As a rule the condition causes no shoulder dysfunction The excessive mobility of the girdles does not impair the efficiency of the extremity Individuals so afflicted can readily bring together the tips of their shoulders in the midline beneath their chins Rarely is any form of therapy indicated Occasionally however one of the free ends of the clavicle presses on the subclavicular structures and in such instances resection of the part is justified

Humerus Varus

The angle of the head of the humerus is less during fetal development than that existing in the adult state But occasionally this fetal type relationship of the head to the shaft of the humerus is found in adults and is designated humerus varus

In the normal humerus the head is directed upward, making an angle of 180 to 140° with the shaft whereas, in humerus varus the head is directed sidewise at an angle of 100° or less. Usually the affection is bilateral.

There is disagreement as to the true cause of this deformity Some workers contend that it is a developmental defect but maintain also that it may be the result of stress applied to soft demineralized bone during the acute phases of such diseases as rickets scurvy and hypothyroidism producing a varus deformity of the humerus similar to that of coxa vara. Cases are on record in which the defect was observed in normal individuals.

Other Congenital Deformities of the Glenohumeral Joint

Two other congenital abnormalities of the glenohumeral joint are encountered occasionally In one the glenoid cavity appears as a convex protuberance which articulates with a concave articular surface on the medial aspect of the head of the humerus (Fig 49B) In the other the glenoid fossa is flattened Brailsford points out that radiographically it appears as if the epiphysis of the lower rim of the glenoid cavity has failed to develop (Fig 49C) the defect is bilateral

Coracoclavicular Joint

Another rare bilateral developmental abnormality is the appearance of a bony process on the inferior aspect of the outer one-third of the clavicle which articulates with a similar process arising from the coracoid process This mechanism replaces the coracoclavicular ligament (the conoid and the trapezoid ligaments) Cases have been reported in which complete ossification of the aforementioned ligaments occurred trauma was the initiating factor in most of them.

Congenital Dislocation of the Shoulder

While such an entity has been definitely established, true congenital dislocation of the shoulder is rarely encountered Undoubtedly many of the reported cases were instances of dislocation sustained at birth or after birth subsequent to some form of obstetric paralysis.

Dislocation occurring at birth is denied by some authorities (Sever, Codman, Taylor) Others are firmly convinced that it occurs at the time of birth and that obstetric palsy is really a pseudoparalysis produced by secondary involvement of the brachial plexus by organizing inflammatory tissue in the axilla (T T Thomas)

The most comprehensive study was made by Grieg (1924) in which the majority of the reported cases were posterior dislocations with a few anterior or inferior dislocations In the posterior type the glenoid was not palpable the head of the humerus occupied a posterior position usually beneath the spine the arm was rotated internally and the forearm was flexed slightly All movements were restricted particularly elevation and external rotation Both the acromion and the coracoid were elongated and bent forward in front of the head of the humerus. No evidence of paralysis of any muscle group exists in these cases Treatment is similar to that described for obstetric palsies

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3

Variational Anatomy and Degenerative Lesions of the Shoulder Joint

GLENOID SIDE OF THE GLENOHUMERAL JOINT
BURSAL SIDE OF THE GLENOHUMERAL JOINT
LESIONS OF THE SHOULDER COMPATIBLE WITH GOOD FUNCTION

INTRODUCTION

Hitherto an orderly study of the variational anatomy and degenerative lesions of the shoulder had not been done Although much information on degenerative alterations of this region may be found in the literature it never has been correlated with a clinical investigation The study recorded in this chapter was divided into two parts.

In the first part of this chapter the detailed variational anatomy of the inside of the glenohumeral joint was studied and the degenerative abnormalities in all the component elements of the shoulder joint were noted Special attention was directed to the changes in the glenoid cavity labrum glenoidale glenohumeral ligaments bursal recesses synovialis tendon of the long head of the biceps brachii muscle and the musculotendinous cuff This phase of the investigation disclosed some very significant observations It became apparent that one unfamiliar with the variational anatomy of this region might readily misinterpret the findings as pathologic or traumatic disorders Also the accumulated data failed to support the rationale of some of the popular operative procedures for stabilization of recurrent dislocation of the shoulder particularly the suspension methods and provides an explanation for the success of others especially those designed to limit external rotation of the extremity such as the Bankart and Putti Platt operation However this study points out that many of the successful procedures are based on false premises

In the discussion on lesions of the shoulder compatible with good function, an attempt was made to evaluate the clinical significance of the observations noted in the first part It soon became evident that degenerative lesions of varying severity were compatible with good shoulder function and that our present day concept of a normal shoulder joint needs revision Furthermore, this investigation disclosed specific degenerative alterations, characterized by a diffuse and progressive process of fibrosis involving all the soft tissue structures of the joint The progressive nature of this abnormality was revealed by the gradual increase in gradient of this lesion in specimens of successive decades especially after the fourth Shoulder joints of the eighth and the ninth decenniums exhibited the most severe changes. As will be shown subsequently the aforementioned degenerative change is responsible for a progressive decrease in the range of external rotation of the arm in normal individuals a feature which cures spontaneously recurrent dislocations of the shoulder and for practical purposes eliminates the disease after the fourth decade On the other hand the same disorder coupled with other factors appears

to be the responsible causative agent for frozen shoulder

A total of 452 shoulder joints were studied Two hundred eight of these were obtained *from cadavers ranging in* age from 14 to 87 years. Of these, 12 were fetuses 6 to 9 months old No clinical histories were available on these specimens One hundred forty four shoulders were obtained postmortem A history was obtained, and an examination of the shoulders was made on the individuals *who provided these specimens, prior to* their death This data was obtained in the following manner All ward patients on the hospital critical list were questioned concerning any joint disorders and their shoulders were examined In case of death the glenohumeral joints with the cuffs intact were removed, dissected and studied Only those joints which failed to give any evidence of disease through history or physical examination were selected for this investigation Furthermore, this group of specimens furnished the material for microscopic study In addition to the above specimens, *100 scapulae, devoid of all soft tissues*, were utilized for detailed macroscopic investigation of the glenoid cavity

The first 96 specimens obtained from cadavers were utilized for *the macroscopic* phase of the investigation After they were mounted and photographed (Fig 50) they were arranged in chronologic order to correlate better the findings from one decade to another From the first 44 postmortem specimens, shoulder joints were selected which were considered representative joints for different decades and whose pathologic alterations corresponded to the representative joints *for each decennium used for* the macroscopic study From these representative joints sections were obtained for microscopic study through all the synovial areas labrum glenoidale biceps tendon, selected areas of the musculotendinous cuff and from the glenoid cavity The findings were also recorded *chronologically* and in tabular form.

For the purpose of study and presentation the glenoid cavity, which is shaped like an inverted comma, was divided into two fields (1) the upper field, designated the tail of the comma, and (2) the lower field, *the head of the* comma These two areas are separated by a transverse line which roughly corresponds to the epiphyseal line of the

GLENOID SIDE OF THE GLENOHUMERAL JOINT

Materials and Methods

Materials Used in Study

Glenoid Side of Scapulohumeral Joint

196 shoulders from cadavers—ranging in age from 14 to 87 years 12 fetuses—ranging in age from 6 to 9 months	No clinical histories or physical examinations were available on these individuals
144 shoulders obtained postmortem	Clinical history and examination of shoulders obtained prior to death

Bursal Side of Scapulohumeral Joint

100 shoulders	No clinical histories or physical examinations were available on these individuals

In addition to the above 100 scapulae devoid of soft tissue were utilized in study on the glenoid cavity

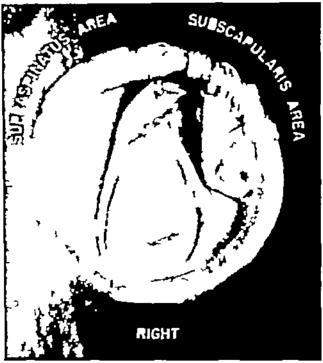


Fig 50 Finished specimen mounted, showing the inside of the glenohumeral joint. Note that the labrum glenoidale surrounding the lower half of the glenoid cavity is continuous with the capsule, while that portion surrounding the upper half is free Also note that the synovial membrane lining the intracapsular structures (the labrum glenoidale the biceps tendon and the glenohumeral ligaments) *is closely adherent to the above structures.* In this specimen the superior glenohumeral ligament is a well-defined and distinct structure. The capsule in the anterior aspect of the shoulder joint is not continuous with the labrum it extends toward the base of the coracoid process from which point it is reflected along the neck of the scapula to the capsular surface of the labrum thereby forming a large synovial recess or pouch

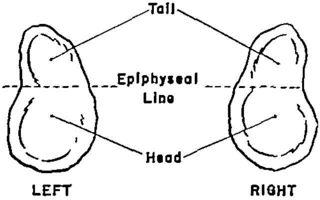


Fig 51 The glenohumeral cavity is shaped like an inverted comma. The upper portion was designated the tail of the comma the lower portion the head of the comma. The transverse line between these two regions roughly corresponds to the epiphyseal line of the glenoid cavity

glenoid cavity (Fig 51) Likewise the synovial membrane was divided into five areas designated (1) the subscapularis area (2) the area of the coracohumeral ligament (3) the supraspinatus area. (4) the infraspinatus and teres minor area and (5) the triceps area (Fig 52)

Synovial pouches found in the anterior aspect of the shoulder joint (often referred to as bursae in textbooks) were found to be related intimately to the middle glenohumeral ligament and tendon of the subscapularis muscle Hence they were designated in accordance with the position occupied relative to these structures. The synovial recess above the middle ligament was designated the superior subscapularis recess The recess below the ligament was designated the inferior subscapularis recess.

The articular cartilage of the glenoid cavity *the glenohumeral ligaments the* labrum glenoidale the biceps tendon and the fibrotendinous capsule were studied separately The degree of the gross alterations noted in all components of each shoulder joint was tabulated in chronologic sequence. Gross changes in the articular cartilage of the glenoid cavity were graded from 1 plus to 4 plus. One plus expressed minimal abnormalities of the articular cartilage as mild surface irregularity or a velvetlike appearance of the superficial cartilage. Severe forms of these alterations plus actual splitting fraying and shallow indentations of the articular cartilage were labeled 2 plus. More marked changes plus an articular surface which exhibited irregular extensive areas of erosion were designated 3 plus. Four plus expressed the maximum degree of degenerative changes encountered in the articulating surface. This included advanced fraying flaking, splitting and erosion of the

cartilage, exposed dense eburnated areas of subchondral bone, and new bone formation

Degenerative changes in the labrum glenoidal and tendon of the long head of the biceps brachii muscle consisted of varying rim of the glenoid cavity in normal shoulder joints Microscopic examination of the cartilage of the glenoid cavity in infant shoulders revealed that it consisted of hyaline cartilage which was thinner in the center of

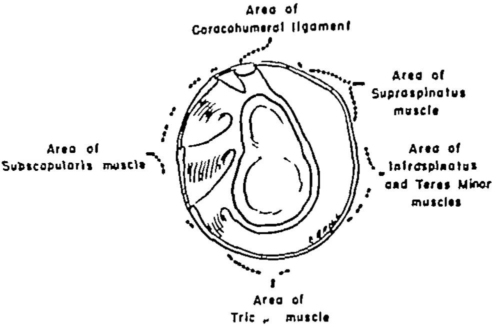


Fig 52 The various designated fields of the synovial membrane

degrees of shredding thinning, thickening, areas of nonattachment of the labrum, and occasionally of partial or complete absence of these structures Changes in the synovial membrane comprised villous formation, synovial tabs and fringes also thickening due to fibrosis in the subsynovial tissues Likewise all of these alterations were graded from 1 plus to 4 plus based on the relative severity of the degenerative changes Abnormalities in the fibrotendinous cuff, demonstrated by such alterations as fraying, shredding and tearing of the structure were likewise evaluated on the extent and the severity of the lesions

Observations Referable to the Glenoid Cavity

The articular surface of the glenoid is a shallow cavity slightly deeper in the region of the head of the comma than in the tail Its depth is augmented by a triangular fibrocartilaginous structure, the labrum glenoidale which is attached firmly to the the head of the comma than in the surrounding areas and the hyaline cartilage in the tail of the comma

The first observation of any significance referable to the articular cartilage was noted in the second decennium No macroscopic changes were demonstrable in the tail of the comma. In the center of the head of the comma a distinct circular area was noted in 4 of the 6 specimens belonging to this decade (Fig 53) It was grossly visible in all specimens for the third and the fourth decades, in 11 out of 12 for the fifth decade in 15 out of 18 for the sixth decade in 29 out of 30 for the seventh decade and in 22 out of 24 for the eighth and the ninth decades

The increased visibility of the area is dependent upon the fact that here the hyaline cartilage is thinner than the surrounding cartilage Also, microscopic examination revealed that the earliest and most severe alterations of the cartilage were found in this area These changes increased in sever

Fig 53 A circular area is barely visible in the center of the head of the comma. This is a specimen of the second decade. In the subscapularis and the coracohumeral areas of the synovial membrane are fingerlike synovial villi projecting into the lumen of the joint cavity

Fig 55 Degenerative changes in the hyaline cartilage in the center of the head of the comma, with formation of connective tissue which assumes the characteristics of imperfectly formed fibrocartilage This is a specimen of the fifth decade. (× 136)

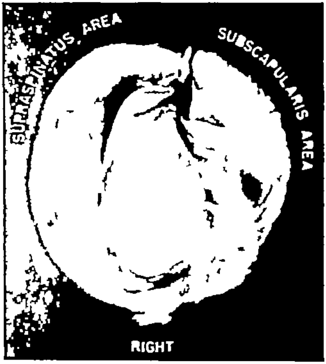
Fig. 54 Typical hyaline cartilage found in the center of the head of the comma in shoulders of infants. (Photomicrograph × 67)

ity in each successive decade leading one to believe that this circular area might be one of greater contact than the surrounding articular cartilage. According to Fick, Poirier was the first to make this observation However he believed this region of the comma's head to be covered with fibrocartilage The findings in this study do not substantiate this observation Microscopic section through the area in question of infant shoulders revealed that hyaline cartilage was the articular tissue found in this region (Fig 54) In specimens of later decades the severe degenerative alterations of the cartilage in the center of the comma's head and metaplasia of the degenerated hyaline cartilage to imperfectly formed fibrocartilage explain how such an erroneous interpretation may be made (Fig 55)

Macroscopically alterations were noted as stated in the articular cartilage of the glenoid cavity as early as the second decade. The bluish white glistening resilient, delicate articular cartilage found in infancy gave way to a firm compact opaque tissue demonstrable as early as the second age

FIG 56 (*Top left*) Papillary velvet like appearance of hyaline cartilage in the head of the comma, due to degenerative changes. Also note that a portion of the biceps tendon is still extrasynovial lying in a tunnel within the fibrous capsule. Circular area in this specimen is well defined. (*Top right*) Maximum degenerative changes in the hyaline cartilage of the glenohumeral cavity, more pronounced in the head of the comma. Note that the intracapsular portion of the biceps tendon is absent, and only a small stub remains attached to the supraglenoid tubercle (*Bottom*) Areas of erosion in the hyaline cartilage in the head of the glenoid cavity, exposing the subchondral bone

period and indicates loss of elasticity With increasing age this alteration in the articular cartilage became more apparent and increased in intensity, reaching its height of progression in the sixth decade In all instances the lesion was more marked in the region of the comma's head Simultaneously, small distinct furrows fibrillation of the superficial layers of the cartilage and softening appeared in and immediately below the central circular area of the head of the comma especially along its ventral



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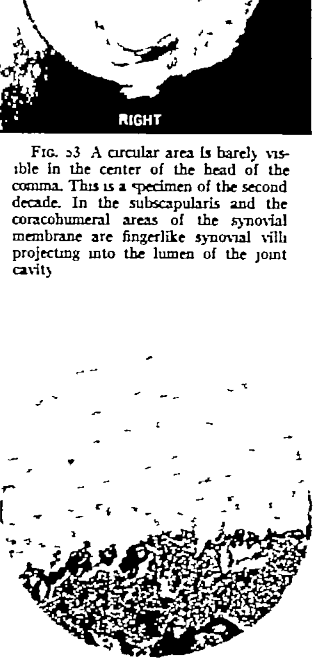

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tive joints in each decade disclosed a gradual, steady progression of pathologic alterations of the articular cartilage, paralleling increasing age Normally, the superficial stratum of hyaline articular cartilage reveals many tightly packed spindle shaped cartilage cells in a dense matrix whose fibrils are arranged parallel with the joint cavity The earliest lesion noted was fibrillation of the superficial layers of the cartilaginous matrix of the hyaline cartilage parallel with the joint space This change was first noted in the second decade

Fibrillation in the deeper strata of the cartilage extending for variable distances was observed to be at right angles to the joint lumen (Fig 57 *top left*) Only the transitional layer of the cartilage down to the calcified zone was involved in specimens of the earlier decades However from the fifth decade on the process extended to the subchondral bone thereby exposing it in many instances.

Cartilage cells adjacent to the fibrillated matrix demonstrated evidence of degeneration The cells were fewer in number below the tangential stratum They appeared to be swollen and their nuclei stained abnormally The normal pattern of the cells in the various layers was lost The cells in the transitional and calcified zones although fewer in number were arranged in groups of varying size

Microscopic study disclosed the progressive nature of the lesions described above with the maximum alterations appearing in the sixth decade (Fig 57 *bottom left*) Lesions of the seventh the eighth and the ninth decades demonstrated no appreciable increase in severity over those of the previous age periods

In this investigation subchondral bony thickening in the ventral and inferior regions of the head of the comma appeared as a frequent abnormality after the fourth decade Thickening was also disclosed in the center of the comma s head after the fifth decade The cartilage overlying the above areas revealed advanced degenerative alterations in mo t instances Evidence of subchondral bony thickening was a rare feature in the tail of the comma where the cartilage lesions were seldom severe This was a constant finding

Histologic examination of sections through the head of the comma in the earlier decades demonstrated only minimal alterations in the subchondral trabeculae As a rule the architecture of the cancellous bone appeared to be normal Occasionally light thickening and indentation of the end plate of the subchondral bone was discernible As a rule, the cartilage over the above areas revealed marked fibrillation fraying and thinning

In later decades, immediately adjacent to the deep layers of the degenerative hyaline cartilage in the center of the comma s head and to the thinned zone of calcification of the hyaline cartilage in its ventral and inferior regions, the bony trabeculae were hypertrophied dense and compact The marrow spaces were small and contained vascular connective tissue. Endosteal cells or osteoblasts lining the trabeculae were discernible in large numbers exhibiting evidence of multiplication and proliferation of endosteal tissue thereby increasing the thickness of the trabeculae by adding newly formed osteoid tissue upon their surfaces (Fig 57 *bottom right*) On several occasions small discrete islets of cartilage were observed in the marrow spaces. This study affords no original explanation for their origin or significance

In this series marginal proliferation of bone and cartilage was di cernible grossly in the region of the tail of the comma in two specimens of the third decade The marginal elevation was more or less symmetrical and involved the entire articular periphery of the comma s tail It was noted that this abnormality increased in frequency and became more prominent in the subsequent decades The labrum glenoidale overlying the rim of the glenoid cavity obscured to a great degree the extent of the lesion in the inferior and ventral regions of the head

and inferior margins where an increase in thickness of the cartilage was also noted

The above lesions have been observed and described adequately by many students of this subject (Bennett and Bauer 1931 Keyes 1933 Parker Keefer Myers, and Irwin 1934 Nichols and Richardson 1909 Bennett and Bauer 1936) These alterations in the successive decades revealed a gradual rise in magnitude the maximum changes being observed in the sixth age period Concurrently the hyaline cartilage of the tail of the comma became involved but to a lesser degree than that of the comma s head With the rise in severity of these pathologic changes the cartilage assumed a papillary or velvetlike appearance (Fig 56 *top*) Occasionally in the older age periods due to thinning fibrillation of cartilage and loss of compact tissue, small irregular, scalloped ulcerated areas were discernible in the articular cartilage, especially in the central inferior and ventral aspects of the comma s head These exposed the subchondral bone which was thickened but never attained a highly polished surface such as described in weight bearing surfaces of the knee joint by Bennett and Bauer 1936, Nichols and Richardson 1909, and Ely 1923 (Fig. 56 *bottom*) Although such lesions were numerous and encountered frequently in this study they never were so extensive as to involve large areas of the glenoid cavity whereby large portions of the subchondral bone were exposed

Microscopic examination of representa

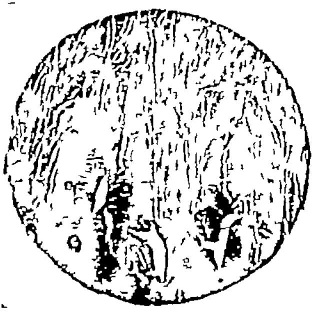
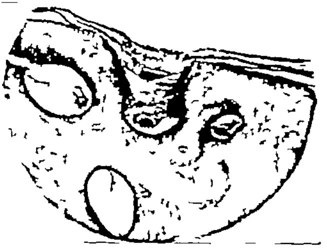


FIG 57 (*Top*) Fibrillation of the superficial layers and vertical splitting of the deeper layers of the hyaline cartilage in the center of the head of the comma. (*Bottom left*) Marked degenerative changes of the hyaline cartilage in the head of the comma in a specimen of the sixth decade Note (1) connective tissue proliferation and metaplasia of hyaline cartilage to imperfectly formed fibrocartilage and (2) grouping of cartilage cells in degenerating cartilage (× 67) (*Bottom right*) Complete degeneration of the hyaline cartilage marked thickening of the subchondral bone narrowing of the marrow spaces and outgrowth of connective tissue from marrow spaces covering the denuded bony surface. (Photomicrograph × 67)



tive joints in each decade disclosed a gradual, steady progression of pathologic alterations of the articular cartilage paralleling increasing age Normally, the superficial stratum of hyaline articular cartilage reveals many tightly packed spindle shaped cartilage cells in a dense matrix whose fibrils are arranged parallel with the joint cavity The earliest lesion noted was fibrillation of the superficial layers of the cartilaginous matrix of the hyaline cartilage parallel with the joint space This change was first noted in the second decade

Fibrillation in the deeper strata of the cartilage extending for variable distances, was observed to be at right angles to the joint lumen (Fig 57 *top left*) Only the transitional layer of the cartilage down to the calcified zone was involved in specimens of the earlier decades However from the fifth decade on the process extended to the subchondral bone thereby exposing it in many instances

Cartilage cells adjacent to the fibrillated matrix demonstrated evidence of degeneration The cells were fewer in number below the tangential stratum They appeared to be swollen and their nuclei stained abnormally The normal pattern of the cells in the various layers was lost The cells in the transitional and calcified zones although fewer in number were arranged in groups of varying size

Microscopic study disclosed the progressive nature of the lesions described above with the maximum alterations appearing in the sixth decade (Fig 57 *bottom left*) Lesions of the seventh, the eighth and the ninth decades demonstrated no appreciable increase in severity over those of the previous age periods

In this investigation subchondral bony thickening in the ventral and inferior regions of the head of the comma appeared as a frequent abnormality after the fourth decade Thickening was also disclosed in the center of the comma s head after the fifth decade The cartilage overlying the above areas revealed advanced degenerative alterations in most instances Evidence of subchondral bony thickening was a rare feature in the tail of the comma where the cartilage lesions were seldom severe This was a constant finding

Histologic examination of sections through the head of the comma in the earlier decades demonstrated only minimal alterations in the subchondral trabeculae As a rule the architecture of the cancellous bone appeared to be normal Occasionally slight thickening and indentation of the end plate of the subchondral bone was discernible As a rule the cartilage over the above areas revealed marked fibrillation, fraying and thinning

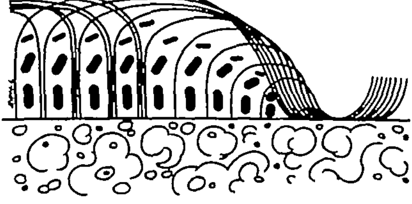
In later decades immediately adjacent to the deep layers of the degenerative hyaline cartilage in the center of the comma s head and to the thinned zone of calcification of the hyaline cartilage in its ventral and inferior regions the bony trabeculae were hypertrophied dense and compact The marrow spaces were small and contained vascular connective tissue. Endosteal cells or osteoblasts lining the trabeculae were discernible in large numbers exhibiting evidence of multiplication and proliferation of endosteal tissue, thereby increasing the thickness of the trabeculae by adding newly formed osteoid tissue upon their surfaces (Fig 57, *bottom right*) On several occasions small discrete islets of cartilage were observed in the marrow spaces This study affords no original explanation for their origin or significance

In this series marginal proliferation of bone and cartilage was discernible grossly in the region of the tail of the comma in two specimens of the third decade The marginal elevation was more or less symmetrical and involved the entire articular periphery of the comma's tail It was noted that this abnormality increased in frequency and became more prominent in the subsequent decades The labrum glenoidale overlying the rim of the glenoid cavity obscured to a great degree the extent of the lesion in the inferior and ventral regions of the head

FIG 58 Note advanced marginal lippings along the rim of the glenoid cavities. The new bone formation is more pronounced along the anterior and inferior portions of the glenoid cavities.

of the comma However investigation of a large series of scapulae denuded of all soft tissue disclosed the maximum degree of new bone formation to be located along the ventral border of the comma especially in its lower region and in the inferior margin of the comma s head (Fig 58) Some degree of macroscopic marginal lipping was noted in all specimens after the third and the fourth decenniums. It was interesting and also of considerable significance to note that there was a close parallelism between the degree of labral detachment and degenerative changes and the prominence of peripheral bone and cartilage formation

The nature and the severity of the alterations detected in the articular cartilage and subchondral bone in the center and the inferior regions of the head of the comma, permit one to conclude that the above areas sustained the greatest functional strain and were areas of greater contact than the remaining portions of the glenoid cavity On the other hand, marginal lipping, especially in the older specimens was found to be a very striking and pronounced alteration located in regions which withstand only minimal pressure It became obvious therefore that a factor other than direct pressure played a greater role in the formation of these peripheral excrescences. The anatomic arrangement of the intracapsular elements of the shoulder joint the relationship of the synovialis and capsule to cartilage and bone at the periphery of the glenoid cavity and the functional demands made



Architectural pattern of collagenous fibers in cartilage (after Benninghoff)

FIG 59 The structural pattern of the collagenous fibers in cartilage as worked out by Benninghoff Note that the fibers at the periphery of the cartilage do not end in the deeper layers of cartilage but are continuous with the fibers of the capsule.

FIG 60 Synovial membrane lining the labrum glenoidale The fibers of the synovialis merge with the superficial fibers of the fibrocartilage but fail to reach the hyaline cartilage of the glenoid cavity Note how the fibers of capsule on the right are continuous with the fibers of the labrum on the left (× 146)

FIG 61 The formation of new bone from the periphery of the glenoid cavity on the right immediately beneath a degenerating labrum glenoidale on the left. Labrum is beginning to tear away from the glenoid rim (× 67)

on this joint may provide a reasonable explanation

Benninghoff (1925) deciphered the structural pattern of hyaline cartilage and correlated it with function He described a system of radial fibrils which arose from the calcified layer of cartilage, ascended radially through the deep and transitional layers to reach the superficial zone, where they ran in a tangential course for varying distances then were deflected into the deeper layers to end in the calcified zone At the periphery of the cartilage the outer segments of the radial fibrils were grouped into a dense layer which became continuous with the fibrous capsule and collagenous fibers of the synovialis Such an arrangement affords a transitional zone of connective tissue between the articular cartilage and the fibrous and synovial capsule and can be considered as a functional adaptation in response to forces of stress and traction at the peripheral joint regions during joint function (Fig 59) However, the relationship of the glenoid cavity and its articular capsule differs from that described above The fibrocartilaginous labrum is interposed between the hyaline cartilage and the fibrous capsule Its glenoid surface is continuous with the fibrous capsule The synovialis, which lines the fibrous capsule projects for varying distances over the labrum and blends with its superficial fibers, but fails to reach the articular cartilage (Fig 60) Also, the outer fibers of the capsule merge with the periosteum below the inferior edges of the labrum glenoidale This region, even in the later age periods, is richly supplied with blood vessels

In this study, microscopic investigation revealed that the most common modes of genesis of marginal proliferations were (1) formation, condensation and projection of subchondral bone into the marginal articular cartilage adjacent to the glenoid surface of the labrum and (2) periosteal bone formation (Fig 61) In some specimens still another mode of bone formation was disclosed Metaplasia of vascular proliferating connective tissue into islands of new bone and imperfectly formed fibrocartilage and hyaline cartilage were observed in the transitional bone between the outer capsular

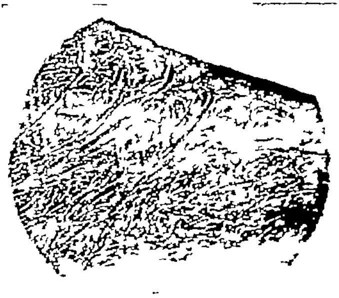


FIG 62 (*Left*) Note that the fibers of the cartilage (below) are continuous with those of the labrum glenoidale (above) (× 67)
FIG 63 (*Right*) Early separation of labrum from glenoid brim Note that line of cleavage is in the fibers of the labrum close to the glenoid brim.

fibers and the periosteum. The prominence of the marginal ridgings paralleled the severity of the alterations in the labrum and the synovialis rather than the changes in the articular cartilage

These observations are compatible with the concept that marginal outgrowths are in response to functional stresses chiefly traction on the outer joint margins Traction and shearing forces acting on the periphery of the glenoid cavity are derived from several sources The fibrous capsule of the glenohumeral joint is a loose redundant structure which allows the humeral head a wide range of motion Thus it is apparent that at the ends of the arcs of motion traction and shearing forces are applied at the peripheral joint margins of the glenoid cavity Furthermore the weight of the upper extremity in a dependent position exerts a definite traction force through the articular capsule at its insertion into the labrum glenoidale and glenoid rim In addition to the above there are two other important factors which are responsible for the formation of marginal excrescences The biceps tendon which is continuous with the superior posterior portion of the labrum glenoidale exerts a distraction force at the glenoid rim in the region of the comma's tail during normal joint function. Likewise the glenohumeral ligaments, which in most instances are attached to the superior and the anterior portions of the labrum maintain sustained traction upon the labrum at the end of the arc of external rotation, thereby tending to pull the labrum from its bony and cartilaginous attachments All these factors furnish stimuli through the media of traction and distraction forces which induce metaplasia of connective tissue in transitional zones hypertrophy of subchondral bone and periosteal bone formation

LABRUM GLENOIDALE AND BICEPS TENDON

The labrum glenoidale is a triangular fibrocartilaginous structure attached by its base to the rim of the glenoid cavity Its glenoid surface is continuous with the hyaline cartilage of the glenoid cavity while its capsular surface blends with the capsule in

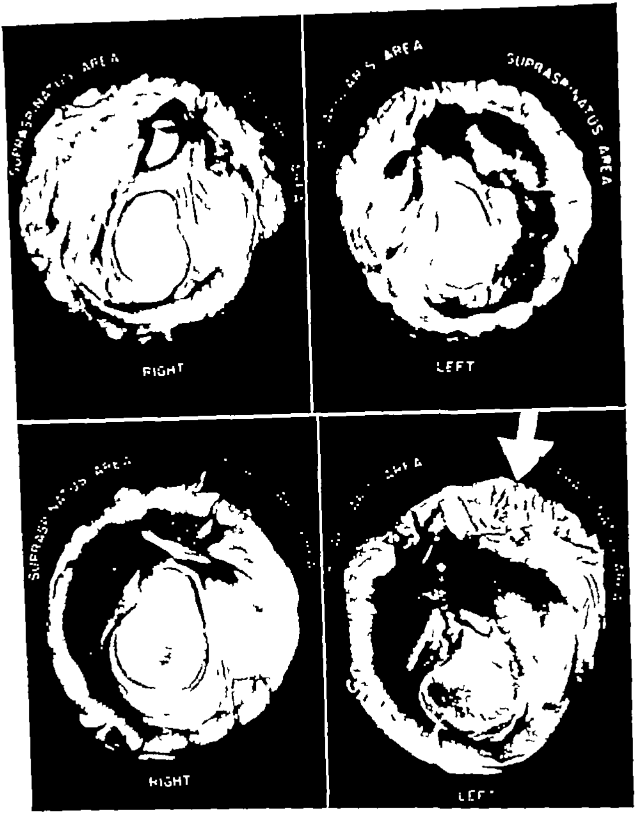


FIG 64 (*Top left*) Early detachment of the labrum from the tail of the comma in a specimen of the second decade. (*Top right*) Further detachment of the labrum from the tail of the comma in a specimen of the third decade (*Bottom left*) Detachment of the labrum from the glenoid cavity in the region of the tail of the comma in a specimen of the fourth decade. Note the well-defined, circular area in the center of the head of the comma. (*Bottom right*) Complete detachment of the labrum from the tail of the comma and the anterior aspect of the glenoid rim in a specimen of the sixth decade. Also note marked thickening of the labrum in the region of the tail of the comma, and thinning of the labrum in the region of the head of the comma where numerous tabs and fringes of synovial and connective tissue are also evident Arrow points to a huge incomplete tear in the supraspinatus and the infraspinatus tendons

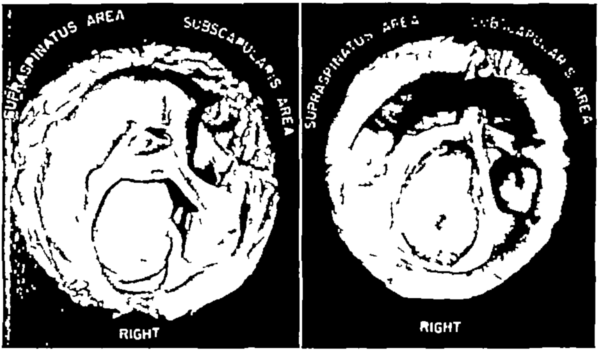


Fig 65 (*Left*) Pronounced detachment of labrum in a specimen of the seventh decade. (*Right*) Labrum detachment in specimen of seventh decade.

the region of the comma s head However that portion around the tail of the comma either may be continuous with the capsule or entirely free (Fig 50) Grossly the structure in most specimens of the second decade was smooth and glistening its edges were sharply defined and it adhered closely to the rim of the glenoid cavity

Microscopic examination of shoulders obtained from infants and from 6- 7 and 8 month fetuses revealed the collagenous fibers of the labrum to be continuous with those of the hyaline cartilage on its glenoid surface and with those of the fibrous capsule on its capsular surface (Fig 62) The synovialis covers the outer portion of its glenoid surface but fails to extend as far as the hyaline cartilage (Fig 60)

Alterations in the labrum were observed as early as the second decade They consisted of slight wrinkling and unevenness of the capsular surface and gross evidence of detachment of its glenoid border from the hyaline cartilage of the glenoid cavity in the region of the tail of the comma (Fig 64) Microscopic examination of specimens of the second decade exhibit a gradual tearing away of the labrum from the glenoid rim. The line of cleavage appears to be through the fibrocartilaginous fibers of the labrum close to the glenoid rim (Fig 63) Such alterations were encountered more frequently and likewise were more pronounced with increasing age In the second decade 16 6 per cent of the specimens demonstrated some degree of nonattachment in the region of the comma s tail in the third and the fourth decades 63 6 per cent in the fifth decade 50 per cent in the sixth decade 72 2 per cent in the seventh decade 96 4 per cent and in the eighth and the ninth decades 100 per cent (Fig 66) From the above observations it is reasonable to conclude that detachment of the labrum is associated with advancing age Moreover the labrum s intimate relationship to the glenohumeral ligaments and the biceps tendon renders it vulnerable to stresses (chiefly to distracting forces) which play a major role in the production of areas of nonattachment

In the light of this information, it is difficult to conceive that labral and capsular defects in the anterior portion of the shoul

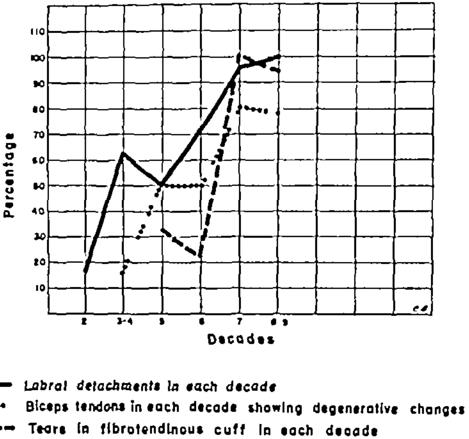


FIG 66 Rise in severity of degenerative changes in the biceps tendon and in the musculotendinous cuff and the increase in the number of labral detachments in successive decades

FIG 67 (*Left*) Marked hyperplasia of detached labrum in the region of the tail of the comma and advanced hypertrophy of all the glenohumeral ligaments There are numerous fringes in the tail region between the hypertrophied labrum and the glenoid cavity

FIG 68 (*Right*) Synovial villi connective tissue tabs and fringes arising from the labrum at the point of detachment from the glenoid cavity (× 71)

der joint are the responsible factors for recurrent dislocations of the shoulder joint. Clinical experience notes that recurrent dislocations are common in the earlier decades *but rare after the fourth decade*, yet this study reveals that the greatest number and the most severe detachments occur in those age periods in which this lesion is only rarely encountered Therefore it is obvious that the agents which play an even greater role in the production of recurrent dislocations of the shoulder joint are other than labral and capsular lesions as described by Bankart Nicola and many others

On the other hand, one can understand readily why the percentage of failures (36 to 40 per cent) is so high when the Nicola procedure or its numerous modifications are used to stabilize recurrent dislocating shoulders The biceps tendon is attached firmly *to the apex of the labrum glenoidale* By virtue of a distracting force upon the labrum incident to joint function it aids in pulling the labrum from its attachment on the glenoid rim. Should the arm be suspended from the apex of the glenoid cavity as is done in the various intracapsular and extracapsular procedures (by anchoring the biceps tendon to the humeral head) the added pull upon the labrum enhances its detachment from the glenoid cavity thereby defeating the very purpose for which the operation was done originally to stabilize the humeral head by the creation of an intracapsular ligament

Hypertrophy of the labrum in the region of the comma s tail was demonstrable as early as the second age period This alteration increased in frequency and degree with each subsequent decennium In fact only one specimen of the third and the fourth decades did not reveal evidence of hyperplasia Tabs and fringes especially along the ventral portion of the glenoid border of the labrum first observed in the second decade were frequent in later age groups and were associated with hypertrophy of the labrum. They were more pronounced in those specimens showing large areas of non attachment. There seems to be a close parallelism between tabs fringes and villous formation and the degree of labral detachment *Specimens of the seventh the eighth* and the ninth decades exhibited the above mentioned alterations in their severest forms (Fig 67)

Microscopic study discloses that tabs, fringes and villi arise from several sources. They may originate from remnants of fibrocartilage on the glenoid border of the labrum or *from those remnants still* attached to the hyaline cartilage of the glenoid cavity, from the transitional zone tissue between the fibrous capsule and the perichondrium of the glenoid cavity from the bone marrow spaces of the glenoid and from the synovialis covering the outer border of the glenoid surface of the labrum glenoidale (*Fig* 68)

In the region of the comma s head labral degenerative changes associated with senescence differ from those in the tail region Whereas hypertrophy of the fibrocartilaginous structure was the outstanding change in the labrum in the tail of the comma thinning fraying and shredding were the usual *alterations encountered* in the head portion (Fig 64 *bottom right*) These changes were first manifested in some specimens of the fifth age period The alterations were frequent, progressing steadily in severity in specimens of the subsequent age groups However such abnormalities were noted also in the anterior portion of the labrum of the tail of the comma in several shoulder joints of the fifth decade and in a few of the following decades Tabs fringes and villi were also *common alterations* noted in this region and not a few specimens demonstrated deposition of calcareous material in the fibers of the labrum and degenerated cartilage in the region of the head of the comma It becomes apparent that such attritional changes are associated with increasing age also they are the result of constant friction between the comma s head

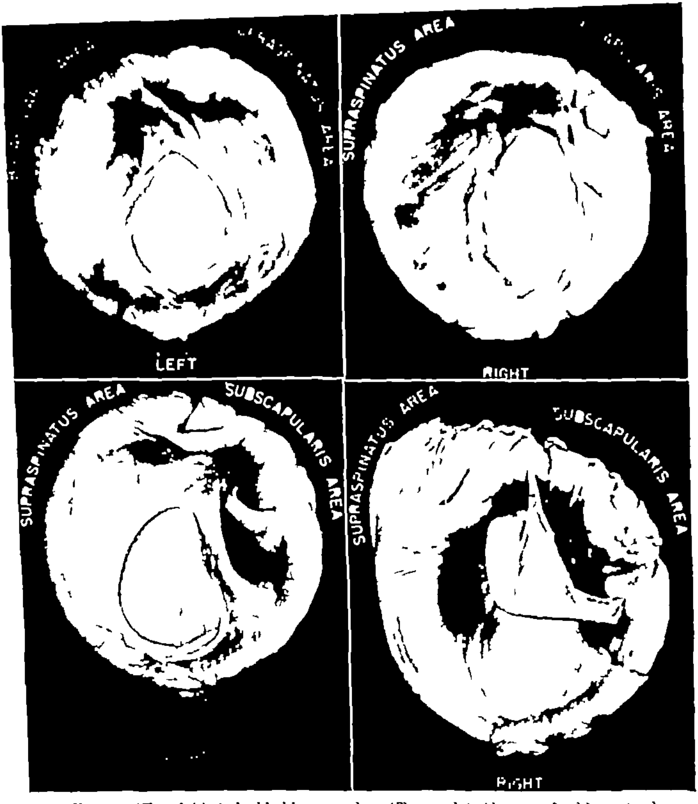


FIG 69 (*Top left*) A double biceps tendon (*Top right*) Absence of a biceps tendon and a firmly attached labrum to the glenoid rim (*Bottom left*) The biceps tendon is extrasynovial lying within the fibrous capsule. This structure has failed to migrate to an intracapsular position Note the firm attachment of the labrum to the rim of the glenoid cavity The inferior glenohumeral ligament in this specimen is well defined and extends from the subscapular area to the triceps area. (*Bottom right*) A well formed mesentery of the biceps tendon and a large incomplete tear in the musculotendinous cuff in the supra spinatus area, proximal to which there is a distinct hypertrophied falciform ligament.

FIG 70 (*Left*) Marked hypertrophy of all the intracapsular structures except the labrum in the region of the comma s head also advanced fraying shredding and hyper trophy of the biceps tendon Note the advanced degenerative lesions in the musculoten dinous cuff of this specimen.

FIG 71 (*Right*) A specimen with complete avulsion of the musculotendinous cuff, ad vanced degenerative changes and hypertrophy of the biceps tendon

and articulating surface of the humerus for evidence points to the fact that this area may be one of greater contact than else where

The intracapsular portion of the biceps tendon occupies a relatively constant posi tion in the superior and slightly anterior region of the shoulder joint It sends fibers into the superior posterior portion of the labrum and in many instances it is at tached to the superior glenohumeral liga ment occasionally to the middle ligament and (in a few instances) to all three gleno-humeral ligaments

Several specimens exhibited various de velopmental abnormalities of the tendon In Figure 56 *top left* the tendon occupied a partially intracapsular position in Figure 69 *top left* it existed as a double structure in Figure 69 *top right* it was absent and in Figure 69 *bottom left* it was entirely within the fibrous capsule Several tendons possessed mesenteries (Fig 69, *bottom right*) No gross degenerative abnormalities were manifest in the biceps tendons until the fourth decade One tendon in this group revealed evidence of widening and thicken ing However the frequency and the promi nence of these alterations showed a progres-sive rise in the subsequent decades. In the fifth decennium 50 per cent of the tendons revealed the above changes in the sixth 50 per cent in the seventh 80 per cent and in the eighth and the ninth, 78 per cent. It was interesting and of some significance to note that the tendons which showed the greatest pathologic disorders were found in specimens which demonstrated severe alter ations in the fibrotendinous cuff (Figs 70 and 71) This observation leads one to be-

FIG 72 Synovial tabs and fringes in the coracohumeral area and a middle glenohumeral ligament which is not continuous with the labrum.

FIG 73 A typical synovial villus and hypertrophy of the synovial membrane (X 145)

lieve that with severe degenerative changes in the rotator cuff, the biceps tendon may be forced to assume the role of the main support for the upper extremity and may be subjected to great attritional forces, thereby accounting in part for the above changes

Many tendons of the later decades revealed marked fraying, shredding and disorganization, in one shoulder joint it was absent Only a small stub of the intracapsular portion remained (Fig 56 *top right*) The intertubercular groove of the corresponding humerus of this specimen was completely obliterated, while the proximal end of the extracapsular portion of the tendon had attained a bony anchorage on the humeral shaft below the level of the intertubercular sulcus

Synovial Membrane

Grossly the synovialis of specimens of the early decades demonstrated several distinct features In the bursal recesses and coracohumeral areas it existed as a more-or less redundant structure from whose surface small fringes tabs or villi project into the joint cavity (Fig 72) Its inner layer consists of densely packed oval or stellate connective tissue cells, elastic fibers, numerous fat cells, scanty matrix and a rich blood supply It merges with an outer fibrous layer rich in collagenous substance but poor in cellular elements The synovial membrane covering the intracapsular elements (glenohumeral ligaments, labrum glenoidale and biceps tendon) is thin, smooth, glistening and closely adherent to the underlying structures (Fig 50) Its inner surface is very thin and delicate, in some areas comprising a single layer of loosely packed flattened cells with little or no subintimal connective tissue

Villous formation and proliferation are indisputable alterations associated with advancing age, although one must concede that other factors such as mechanical and chemical irritation of the synovialis, also may be responsible for these changes They may exist as fine fingerlike projections or as branching papillary or even polypoid structures Their histologic structure con

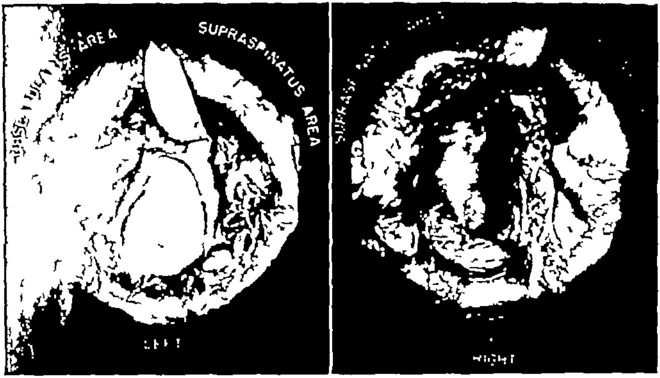


FIG 74 Advanced villous hypertrophy and proliferation of the synovial membrane. Also thickening of the intracapsular structures so that the synovial recesses are practically obliterated. The corresponding humeral heads of both these specimens exhibited evidence of severe trauma.

sists essentially of a fine connective tissue core containing fat cells and capillary blood vessels and enclosed by enveloping layers of specialized connective tissue (synovial cells) Lymphoid and plasma cells are present in varying numbers within the connective tissue stalks (Fig 73) In this investigation villi were detected as early as the second decade in the subscapularis and coracohumeral areas (Figs 53 and 72)

These abnormalities of the synovial membrane were observed frequently in many specimens of the third the fourth and the fifth decades. Although relatively slight there was a definite increase in gradient up to the sixth decennium Moreover in many specimens of the fourth and the fifth age periods the above alterations were not only disclosed in the subscapularis and coracohumeral regions of the joint but also in the other areas of the synovial membranes especially in the infraspinatus and teres minor and triceps areas Generally speaking villous projections and proliferations in specimens of the sixth, the seventh the eighth and the ninth decades surpassed in prominence those noted in the previous are periods

Figure 74 demonstrates the effect of trauma on the synovialis. The corresponding humeral heads of these shoulder joints disclosed marked irregularity of their articular surfaces secondary to malunited fractures of the anatomic necks. The resulting incongruity of the articulating surfaces inflicted repeated trauma to the synovial tissues The trauma was undoubtedly responsible for the reactionary response noted in the synovial membranes of the above shoulder joints As the photographs show both the shoulder joints revealed numerous villi of varying sizes and shapes arising from all fields of the synovial membrane however the villi were more pronounced in the infraspinatus and teres minor area Many of the villi were rounded thickened,

FIG 75 (*Left*) Numerous tabs and fringes between the labrum and the glenoid cavity, as if an attempt were being made to reattach the labrum to the glenoid rim.

FIG 76 (*Right*) Calcareous deposits in the degenerated cartilage in the head of the comma and tabs and fringes covering surface of the labrum In the supraspinatus area, a large defect exists in the musculotendinous cuff, proximal to which there is a well formed falciform ligament.

stubby and of yellow color being heavily laden with fat cells while others were fine, fingerlike branching projections

Although both joints presented advanced synovial impairment the articular cartilage in Figure 74 *left* exhibited only minimal alterations while that in Figure 74 *right* far advanced degenerative changes This last observation supports the concept that degenerative articular changes are primary and not secondary to synovial abnormalities As a rule however specimens which showed great impairment of the articular cartilage also demonstrated severe lesions of the synovial lining Secondary changes were not infrequently noted in villi especially in the later decades The most common alteration was hyaline degeneration of the connective tissue in some instances, formation of imperfect cartilage was observed

Tabs and fringes, arising from the labrum glenoidale and the glenoid rim were observed in some specimens of the second decade They increased in size and number from decade to decade Only two specimens in the fifth decade failed to show these alterations they were present in all specimens of the sixth, the seventh, the eighth and the ninth age periods As previously stated, such abnormalities were associated chiefly with detached labra. Grossly and microscopically, they originated from the synovial lining over the labrum, from the glenoid border of the labrum and from the periphery of the glenoid rim. As a rule they were concentrated in the region of the tail of the comma and along the ventral margin of the glenoid cavity in which areas labral detachments were most commonly observed There was a close parallelism between the prominence of these changes and the degree

FIG 77 Advanced degeneration of the synovial membrane in the falciform ligament. Note marked fibrous tissue proliferation and hyalinization of this tissue (× 67)

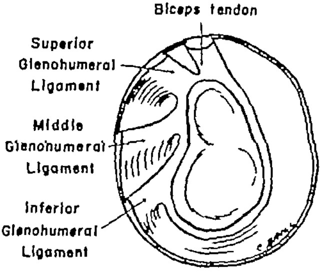


FIG 78 Schematic representation of superior middle and inferior glenohumeral ligaments. They converge from the humerus toward the ventral border of the glenoid cavity, to be continuous with the labrum and the biceps tendon

of labral detachment Microscopically, the tabs arising from the capsular border of the labrum consisted of irregularly shaped synovial villi of varying sizes similar to those arising from the synovial membrane in the subscapularis region Those originating from the glenoid rim and fibrocartilage consisted of irregular frayed portions of fibrocartilage many of which were undergoing hyalinization Moreover some of these tabs and fringes were composed of connective tissue arising from the vascular transitional zone between the fibrous capsule and the perichondrium while others arose directly from the peripheral narrow spaces of the cancellous bone In the later decades many specimens revealed the space between the glenoid rim and detached labrum to be obliterated partially or completely by numerous tabs and fringes as if an attempt were being made to reattach the labrum to the glenoid rim (Figs 75 and 76) These degenerative structures showed many secondary changes especially in the older specimens The changes comprised chiefly hyalinization and calcareous material within these projections (Fig 76)

Hypertrophy of the synovial membrane, due to fibrosis of the subintimal connective tissue was noted as early as the third and the fourth decades In the subsequent age groups there was a gradual, progressive rise in the intensity of this process The structures which were subjected to constant functional stress disclosed the greatest amount of thickening Thus there were marked hyperplastic changes in the glenohumeral ligaments the biceps tendon the superior portion of the labrum which is continuous with the biceps tendon and the superior glenohumeral ligament and the ventral segment of the labrum which is attached to some or all of the glenohumeral ligaments In some instances the increase in thickness of the above structures and of the total synovial lining was so great that the synovial pouches in the anterior aspect of the shoulder joint were reduced in size or were obliterated completely (Fig 74)

Macroscopic tears in the synovial membrane were first noted in the fifth decade and they were associated with degenerative defects in the corresponding areas of fibrotendinous cuff Proximal to the cuff lesion

Fig 79 A well formed middle glenohumeral ligament below the level of the superior glenohumeral ligament Also a large superior subscapularis recess and a still larger inferior subscapularis recess which may be interpreted erroneously as a rent in the capsule.

the synovial membrane always was found torn (Fig 64, *bottom left*) It became apparent that the synovial and fibrotendinous alterations occurred simultaneously The proximal edge of the synovial defect became thickened, smooth and glistening and formed a falciform ligament across the defect in the fibrotendinous cuff In this study the synovial lesions paralleled in number and severity the alterations in the fibrotendinous cuffs Microscopic study of sections through the above falciform ligaments revealed marked hyperplasia of the subintimal connective tissue and a scarcity of cellular elements (Fig 77) Hyalinization of the synovial membrane was a frequent finding Not infrequently, metaplasia of the connective tissue of the subintimal stratum resulted in the formation of fibrocartilage.

Glenohumeral Ligaments and Synovial Recesses

The fibrous capsule is reinforced anteriorly by three ligaments designated as the superior, the middle and the inferior gleno-

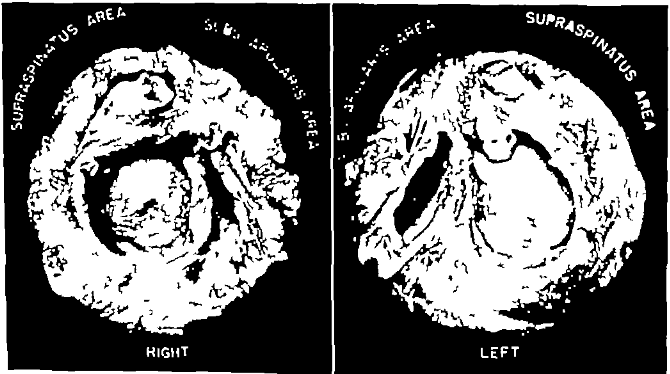
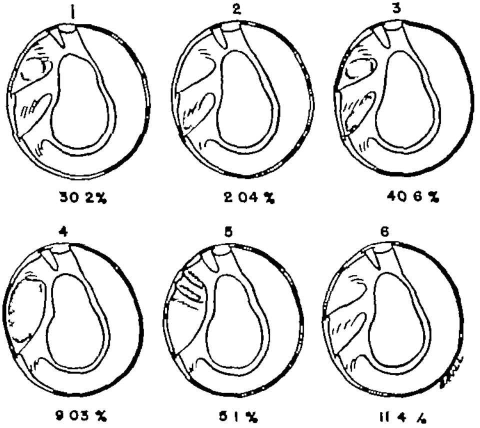


Fig 80 Marked hypertrophy of the synovialis and all intracapsular elements tending to obliterate the synovial recesses and the pattern of arrangement of the glenohumeral ligaments.

humeral ligaments (Fig 78) Generally speaking, they converge from the humerus toward the ventral border of the glenoid cavity, to be continuous with the labrum glenoidale and the biceps tendon They limit external rotation by acting as check reins. In the anterior portion of the shoulder joint are found *synovial recesses*, whose number size and location show considerable variation This variability is dependent largely on the topographic variations of the glenohumeral ligaments

MIDDLE GLENOHUMERAL LIGAMENT

The middle glenohumeral ligament is a variable structure In the 96 specimens of this study, it was found as a well formed distinct structure in 68, it was poorly defined in 16 and absent in 12 When present it arises in most specimens from the labrum, immediately below the superior ligament, and from the neck of the scapula (Fig 79) It inserts into the lesser tuberosity in relationship *with the subscapularis tendon* Occasionally, it arises only from the labrum. At other times it may have no attachment to it (Fig 72) In a few specimens it exists as a double structure, in the anterior portion of the capsule, having no connection with the labrum, the superior ligament or the scapula Length width and thickness vary considerably Such variability was



Types of arrangements of synovial recesses

FIG 81 Six types of arrangement of the synovial recesses (1) Characterized by one synovial recess above the middle glenohumeral ligament, (2) One synovial recess below the glenohumeral ligament. (3) Two synovial recesses. A superior subscapular recess above the glenohumeral ligament, and an inferior subscapular recess below the glenohumeral ligament. (4) One large synovial recess above the inferior glenohumeral ligament the middle glenohumeral ligament is absent. (5) The middle ligament exists as two small synovial folds. (6) Complete absence of synovial recesses.

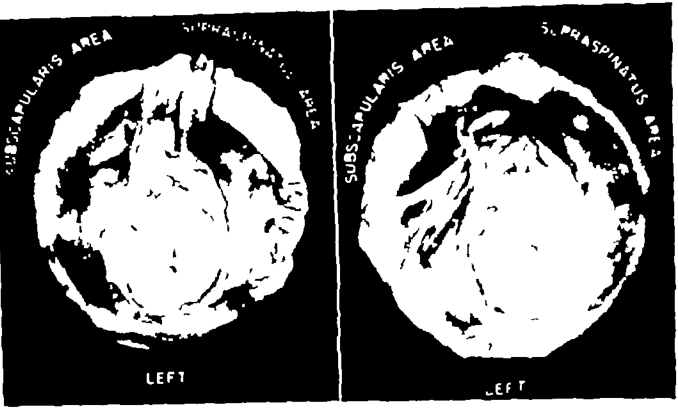


FIG 82 (*Left*) Small synovial recesses above and below the middle glenohumeral ligament. (*Right*) Large synovial recess above the middle glenohumeral ligament. This recess may be interpreted erroneously as a rent in the capsule.

more pronounced in specimens of the later decades. This was due partially to developmental reasons and partially to alterations in the synovial membranes The marked fibrosis noted in the synovial tissues lining the fibrous capsules was disclosed also in the synovial membranes covering the glenohumeral ligaments Moreover there was profound hyperplasia of the fibrous tissue elements of the ligaments (Fig 80)

The variable topographic relationship of the glenohumeral ligaments to the synovial recesses gave rise to six distinct variations designated as Types I II III IV V and VI Type I was observed in 30 2 per cent of the specimens Type II in 2 04 per cent Type III in 40 6 per cent Type IV in 9 03 per cent Type V in 5 1 per cent and Type VI in 11 4 per cent (Fig 81) These are developmental types for they were present also in infant shoulders However because of progressive soft tissue changes the different types may lose their distinguishing features

Figure 80 revealed such profound alterations in the synovial tissues and all intracapsular structures that the synovial recesses were indiscernible, and the glenohumeral ligaments were barely distinguishable One can assume, therefore, that the hyperplastic processes in the synovial tissues and fibrous capsules of these shoulder joints obliterated the recesses, if present, and distorted the distinctive characteristics of the glenohumeral ligaments

The size of both the superior and the inferior subscapularis recesses, demonstrated extreme variability regardless of the type in which they are found They may be very small as in Figure 82 *left* or very large as in Figures 82 *right* and 80, *right* With advancing age there is a tendency for the recesses to become smaller and in some instances, obliterated by increased thickness of the capsular tissues

Besides physiologic aging, another factor plays a major role in the production of the above findings It is generally agreed that

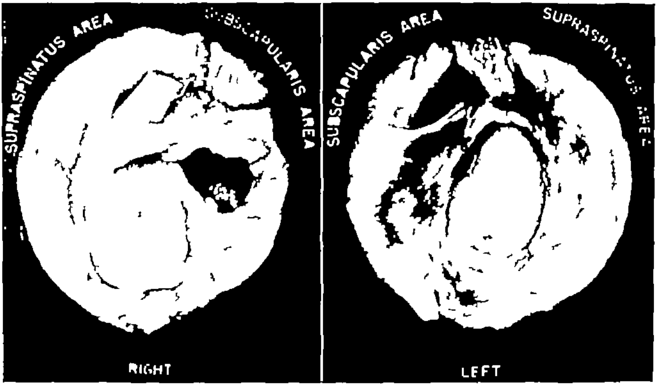


FIG 83 (*Left*) Hypertrophied middle glenohumeral ligament, below which is a large inferior subscapularis recess. The recess may be mistaken for a rent in the capsule, and the middle ligament as a detached labrum.
FIG 84 (*Right*) Ill-defined inferior glenohumeral ligament. It exists as a diffuse thickening of the synovial membrane between the subscapular area and the triceps area.

soft tissues subjected to constant functional stress respond by becoming hypertrophied The glenohumeral ligaments restrict external rotation of the arm. Therefore it is plausible to assume that over a period of years this function causes hypertrophy of the glenohumeral ligaments

The anatomic relationship of the middle glenohumeral ligament to the inferior subscapularis recess is of singular clinical significance for it may be interpreted erroneously as a traumatic or pathologic disorder associated with or responsible for recurrent dislocations of a shoulder joint In the presence of a large recess and a distinct middle ligament, a surgeon exploring the shoulder joint may readily misinterpret the recess as a rent in the capsule and the ligament as a torn and displaced labrum. Figures 79 and 83 clearly illustrate the grounds for such a possibility

SUPERIOR GLENOHUMERAL LIGAMENT

This structure was the most constant of all the glenohumeral ligaments (Fig 50) It was identified as a distinct structure in 94 specimens and was absent in 2 It arose from the upper pole of the glenoid cavity and the root of the coracoid process. In 73 of the 96 shoulders studied it was found attached to the middle glenohumeral ligament to the biceps tendon and to the labrum in 20 to the biceps tendon and the labrum in 1 to the biceps tendon only and in 2 to the middle ligament the inferior ligament and the labrum, but not to the biceps tendon

Many years ago Schlemm considered it as the deep portion of the coracohumeral ligament It inserts in the fovea capitis of the humerus adjacent to the lesser tuberosity in relationship to the portion of the coracohumeral ligament that inserts into

this tuberosity Frequently, the capsular portion of the superior glenohumeral ligament projected into the lumen of the joint This condition was constant in the newborn child, in the frog and the guinea pig Welcher (1877) compared this ligament with the round ligament of the hip joint and found that, during its development, it shifted from an extracapsular to an intracapsular position Accordingly, the visibility of this ligament from the synovial side of the capsule will vary

Like the middle ligament the superior glenohumeral ligament varied considerably in size, although its anatomic position was constant There was progressive thickening of this structure with increasing age This change was the direct result of hypertrophy of the synovial and the fibrous capsule associated with senescence The hyperplastic process may be so advanced that the identity of the structure is obscured

Ninety four of the specimens disclosed the superior ligament attached to the labrum This observation was of some significance for the labrum in the tail of the comma showed evidence of detachment as early as the second decade The frequency and the degree of this abnormality increased with each subsequent decade It is reasonable to conclude, therefore that the superior glenohumeral ligament together with the biceps tendon exerted a distracting force upon the labrum in this region, thus causing this structure to be pulled away from the glenoid cavity

Inferior Glenohumeral Ligament

The inferior glenohumeral ligament is a triangular-shaped structure with its apex at the labrum and its base blending with the capsule between the subscapularis area and the triceps area thus reinforcing this region (Fig 69 *bottom left*) Often it is a very indistinct structure and exists only as a diffuse thickening of the capsule (Fig 84) In this study it was observed as a well defined ligament in 54 shoulder joints poorly defined or indistinct in 18 and absent in 24

Degenerative alterations affecting this structure were similar to those described for the middle and the superior ligaments They chiefly comprised thickening of the synovial and fibrous elements of the structure Together with the other two ligamentous structures, it plays an important role in detaching the labrum from its anterior attachment to the glenoid cavity and in the formation of bony excrescences

Musculotendinous Cuff

The fibrous capsule of the glenohumeral joint is a loose, redundant structure, whose surface area is approximately twice that of the anatomic head of the humerus Such laxity of the capsule permits wide arcs of motion of the humeral head in all directions It arises from the margin of the glenoid cavity and the capsular surface of the labrum In specimens possessing large synovial recesses, the fibrous capsule is not continuous with the labrum glenoidale, anteriorly, but it extends mesially to the base of the coracoid process and then reflects as a very thin structure (consisting of a thin layer of fibrous tissue covered with synovial membrane) along the ventral surface of the neck of the scapula to the labrum (Fig 50) In the region of the tail of the comma, the capsule usually does not encrouch upon the labrum The tendons of the short rotator muscles (supraspinatus infraspinatus teres minor and subscapularis) reinforce the upper half of the fibrous capsule by merging with its fibers Commingling of the tendon and the capsular fibers is so complete that it is impossible to separate them even by sharp dissection Close to their insertion into the sulcus of the humerus it is impossible, even microscopically to distinguished tendon fibers from capsular fibers Moreover the fibers of the rotator tendons not only interlace with the capsular fibers but also with one another

Fig 85 Severe incomplete tears of the musculotendinous cuff in the region of the subscapular area and the supraspinatus and infraspinatus areas.

Gross lesions on the synovial side of the fibrotendinous cuff were first noted in the fifth decade The alterations consisted of shredding fraying and tearing of the inner most fibers of the cuff in the regions of the supraspinatus and the subscapularis tendons (Fig 85) Many specimens of the later decades revealed involvement of the entire thickness of the musculotendinous cuff thus showing a defect which is referred to clinically as a complete tear

As recorded previously the synovial tissues proximal to the defects were always torn thickened and smooth forming falciform ligaments across the defect (Fig 75) The frequency and the magnitude of these degenerative changes rose steadily with advancing age. In the fifth decade there were cuff tears of some degree in 4 out of 12 shoulder joints in the sixth in 4 out of 18 in the seventh in 30 out of 30 in the eighth and the ninth, in 23 out of 24 (Fig 66) Hitherto, one was prone to believe that the supraspinatus area was most often affected However, this study disclosed that degenerative alterations are encountered more frequently, though less severely, in the subscapularis region of the musculotendinous structure Forty-one per cent of the shoulder joints demonstrated lesions in the subscapularis tendon, while 24 per cent showed lesions in the supraspinatus tendon.

Involvement of the infraspinatus tendon was noted in 13 per cent. It was never found as a single lesion but always was associated with a tear of the supraspinatus area. On the other hand, tears in the supraspinatus tendon without extension into the infraspinatus area were recorded in 45.8 per cent of the specimens with lesions in the supraspinatus region of the cuff Double tears (lesions in both the supraspinatus and the subscapularis regions) were revealed in 34 4 per cent of the specimens, showing gross degenerative changes in the musculotendinous cuff Two double tears were found in the fifth decennium 2 in the sixth 7 in the seventh and 10 in the eighth and the ninth. One specimen (Fig 71) demonstrated an avulsion of the entire musculotendinous cuff The increase in percentage of tears together with the rise in the magnitude of the lesions in successive age periods indicates that the severe total capsular alterations observed in the seventh the eighth and the ninth age periods are intimately related with senescence Although other factors may participate in the production of the above lesions physiologic aging plays a great role

Microscopic alterations in the musculotendinous cuff were observed in shoulder joints as early as the third decade The lesions comprised tearing fraying and hyalinization of the collagenous fibers increased vascularity and fibrosis Specimens of subsequent age periods revealed a gradual advance in gradient of the pathologic changes. The most pronounced lesions were found in the seventh the eighth and the ninth dec

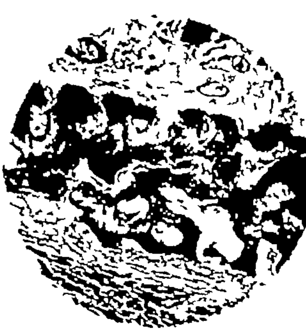


FIG 86 (*Left*) Bone formation within the hypertrophied synovial membrane overlying the musculotendinous cuff in the region of the supraspinatus area (× 65)

FIG 87 (*Right*) Severe degenerative changes, characterized by shredding and tearing of the fibers of the supraspinatus tendon Further note transformation of these fibers to fibrocartilage in the region of their point of insertion into the humeral head. (× 67)

ades After the third age period all shoulder joints disclosed some microscopic impairment in the musculotendinous cuff As a rule the lesions were encountered more frequently and *were of greater severity in the* supraspinatus and the subscapularis areas than in the other capsular regions Metaplasia of connective tissue was not an uncommon observation after the fifth age period Imperfectly formed fibrocartilage osteoid tissue and in several specimens bone *formation were frequently encountered* (Fig 86) The most constant alterations noted in the late age periods were hyalinization and transformation of the fibers of the musculotendinous cuff into fibrocartilage at *its point of attachment to the humeral head* (Fig 87)

The above observations referable to the fibrous capsule of the shoulder joint differ from those recorded on the knee joint by Nichols and Richardson who observed that the capsule is not thickened, although the fibrous tissue of which it is composed may be exceedingly dense ' Parker Keefer Myers and Irwin noted that "the capsule of the joint was as a rule, not thickened although in the cases in which the capsule was stretched the fibrous tissue was extremely tough and of increased density

In this study, the degree of impairment found in the capsular elements generally surpassed those in the bony and cartilaginous elements of the shoulder joints Moreover, whereas the maximum level of pathologic changes in the cartilage was attained in the sixth decade the capsular lesions *showed a steady increase in gradient* to the ninth decennium

Although aging is a major factor, it becomes apparent that other agents participate in the production of advanced changes observed in many specimens of the eventh the eighth and the ninth decades The musculotendinous portion of the capsule of the shoulder joint possesses a unique anatomic position It occupies a site between the acromion and the humeral head Thus it is vulnerable to repeated injuries by being compressed between these two bony points during various positions of abduction and elevation of the arm Stevens further

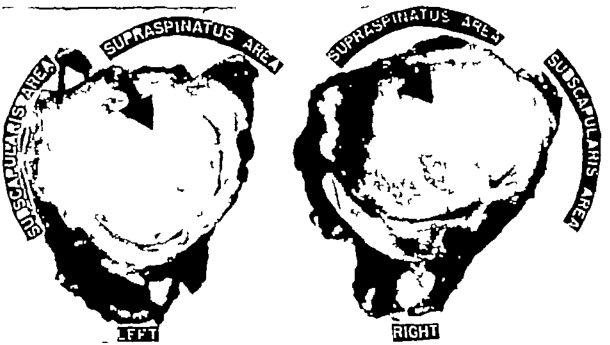


FIG 88 Paired specimens from an individual 48 years of age. Arrows point to the irregularities in the floor of the subacromial bursa. This is a view looking directly on top of the bursa the roof of the bursa has been excised in both specimens. Degenerative areas are observed at points making greater contact with the acromion

noted that failure of the rotator muscles to stabilize the humeral head against the glenoid cavity during abduction causes an upward thrust of the head against the inferior surface of the acromion thereby pinching and compressing the intervening soft tissue structures Moreover the rotator apparatus functions as the short arm of a long lever This predisposes the musculotendinous cuff to repeated strain Strains are produced also by various occupations which demand that the arm function in slightly abducted positions The accumulative effect of slight repeated traumata over many years is partially responsible for the advanced degenerative and attritional changes in capsular tissues of the shoulder joints in the late periods of life.

BURSAL SIDE OF THE GLENOHUMERAL JOINT

One hundred shoulder joints obtained from cadavers ranging in age from 19 to 88 years furnished the material for this investigation The progressive rise in severity of degenerative lesions observed in this study paralleled the alterations recorded above for the glenoid side of the cuff

SUBACROMIAL BURSA

In infant shoulders the roof and the lateral walls of the subacromial bursa consisted of a filmy transparent delicate membrane Occasionally a fold was demonstrable separating the subacromial portion of the bursa from the subcoracoid portion. Specimens of later age periods in which there was evidence of advanced degenerative changes in the cuff exhibited thickened bursal walls and not infrequently the bursa was divided into several separate cavities by thick smooth adhesions. In all instances of a complete rupture of the cuff (in which there was direct communication between the joint and the subacromial bursa) the bursa was markedly enlarged in all its dimensions and its walls were hypertrophied and thickened In fact in shoulder joints with complete avulsion of the rotator cuff the humeral head lay under the roof of the

subacromial bursa It is reasonable to think that the increase in the size of the bursa in these instances is in response to the presence of synovial fluid which constantly distends the bursal sac during abduction and elevation of the arm

It is an accepted clinical fact that frozen shoulders never are encountered in patients with complete tears of the cuffs One may assume therefore, that the presence of synovial fluid within the bursa prohibits the formation of an adhesive type of bursitis or tendinitis which may initiate pathologic processes responsible for frozen shoulder

In a few shoulder joints of aged individuals the bursa was completely obliterated There was discernible no interval between the subdeltoid fascia and the outer surface of the rotator cuff Sharp dissection was necessary to separate the deltoid muscle from the outer surface of the musculotendinous cuff All these specimens disclosed rotator cuffs which were intact but grossly degenerated

Floor of the Bursa and the Outer Surface of the Rotator Cuff

The intimate association of the floor of the subacromial bursa with the outer surface of the rotator cuff, makes it necessary to discuss these two structures as a unit.

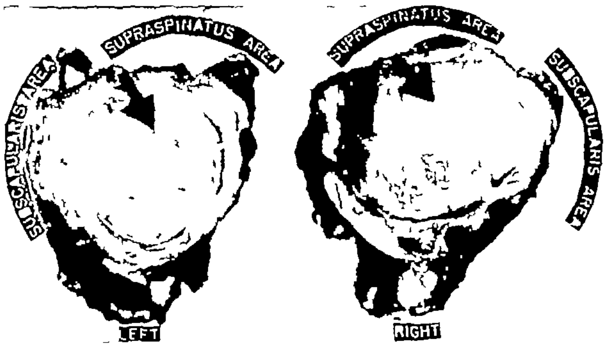
Normally the base of the bursa is firmly adherent to the upper and outer portion of the greater tuberosity and to the rotator cuff where it inserts into the tuberosities Its base bridges the bicipital sulcus In infant shoulders and those of early decenniums the floor of the bursa was smooth, glistening and transparent Palpation from within the bursa revealed that the tuberosities and the edge of the acromion were smooth and regular Upon abduction and elevation of the humerus, the base of the bursa passed beneath the coraco-acromial ligaments and the acromion without impingement

Several specimens of the fifth decade exhibited gross manifestations of degenerative changes which increased in frequency and severity in each subsequent decennium Impairment of the base of the bursa depended upon the degree of the alterations in the underlying rotator cuff Thickening of the synovial lining villous formations and tabs were the lesions encountered most frequently As a rule, they were associated *with thinning, tearing, shredding* and lamination of the rotator cuff fibers particularly in the supraspinatus and the infraspinatus regions (Fig 88) In one specimen, the entire bursa was packed with numerous filmy, branching synovial villi arising from the base of the bursa A small complete tear was also observed in the supraspinatus tendon

As pointed out by Codman, concentration of bursal lesions in the supraspinatus region leads one to believe that this is an area of greater stress and strain and, upon elevation of the extremity, more likely to impinge against the coraco-acromial ligament and the acromion than are the remaining portions of the cuff

Macroscopic calcareous deposits never were observed within the bursa. However in two specimens numerous small and discrete yellowish calcareous nodules were encountered beneath the floor of the bursa. They lay within the fibers of the supraspinatus and the infraspinatus tendons just proximal to their line of insertion into the facets of the greater tuberosity (Fig 89 *left*) Another specimen exhibited one large round deposit measuring one quarter of an inch in diameter and one eighth of an inch high in the supraspinatus area The floor of the bursa was stretched tightly over it and, upon abduction and elevation of the humerus the nodule impinged against the edge of the coraco-acromial ligament and the acromion (Fig 89, *right*) It became obvious that such lesions may give rise to symptoms by irritation of the floor of the bursa and also by acting as a mechanical obstacle to free motion in abduction and elevation of the extremity

Though not common, microscopic deposits of calcium were encountered more



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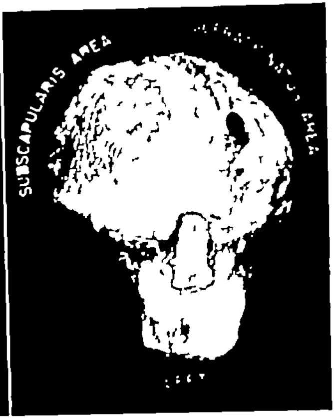


FIG 91 (*Top left*) Small longitudinal tear at junction of supraspinatus and infraspinatus tendons. Biceps tendon has been reflected upward and its inner edge is frayed. (*Top right*) Small complete tear in supraspinatus area of cuff Note slight elongation of circular defect (*Bottom*) Same features as above

Macroscopic degenerative changes were first noted in the cuff in specimens of the fourth period of life Essentially, the lesions comprised thinning shredding lamination and tears of varying degree of the cuff Although abnormalities were observed more frequently in the subscapularis region of the inner side of the cuff they were encountered more frequently in the supraspinatus area of the outer side of the cuff Thinning of the tendon proximal to its line of insertion into the facet of the tuberosity was the lesion encountered most frequently In some specimens the continuity of the cuff was maintained only by a thin ribbon of tissue In many specimens the cuff on the inner side was thickened and hypertrophied proximal to this thin band Such a hyperplastic process was nature's attempt to repair the defect All the defects on the synovial side of the cuff as previously noted were limited by a thickened synovial falciform edge also the result of a reparative process In this series 13 complete tears of varying degree were observed (13 per cent) Figures 91 to 99 show the tears encountered The first complete tear was found in the fifth decennium

Fig 89 (*Left*) Arrows point to calcareous deposits within the musculotendinous cuff The floor of the bursa is stretched tightly over the calcareous areas. (*Right*) Large calcareous deposit in supraspinatus portion of musculotendinous cuff On abduction of the humerus this mass impinged against the acromion and the acromioclavicular ligament.

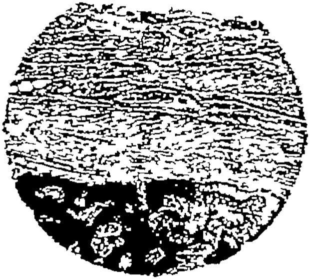


Fig 90 Well formed bone tissue appears in the supraspinatus tendon. The patient is 52 years of age and had no pain or shoulder dysfunction. (× 66)

frequently than macroscopic deposits It was significant that calcium deposits always were associated with gross evidence of degenerative changes in the musculotendinous cuff This observation has been recorded by many observers and forces one to conclude that such lesions in this region are manifestations of degenerative alterations

Osseous tissue in the cuff was disclosed in three specimens (Fig 90) It was observed in the supraspinatus tendon in 2 specimens in the third the tendons of the supraspinatus the infraspinatus and the teres minor muscles were converted into a continuous shell of dense bone

The rotator tendons revealed a diversity of pathologic alterations which increased in severity in each subsequent decennium

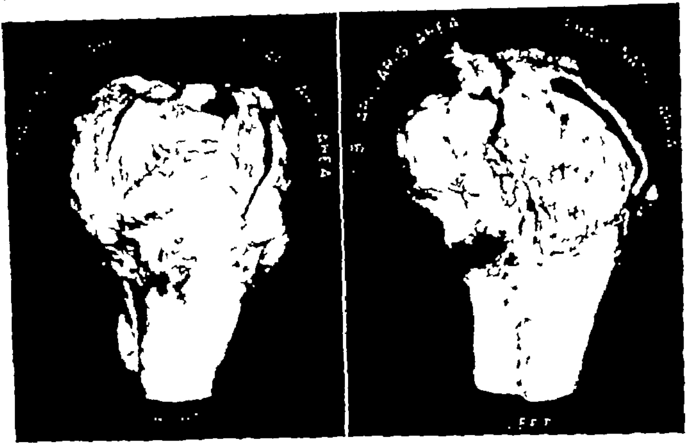


FIG 93 (*Left*) Advanced tearing away of fibers from the humeral head and longitudinal splitting of the cuff Note secondary split in infraspinatus area of the cuff, converting this portion of remaining cuff into a ribbon Atrophy and recession of the tuberosities are pronounced The tear crossed the groove to involve the upper portion of the subscapularis tendon. The biceps tendon exhibits severe shredding, thickening and hypertrophy

FIG 94 (*Right*) Elongation of tear is very evident approximating a triangular defect. Its edges are smooth and thin the tuberosities are atrophic and disclose pronounced roughening The biceps tendon is frayed, shredded and thin. No vestige of the distal end of the cuff remains The defect involves both the infraspinatus and the supraspinatus areas.

by Codman) palpable to the examiner and the patient in shoulders with a partial or complete tear of the rotator cuff

Other specimens revealed pronounced atrophy of the cuff proximal to the thinned portion inserted into the tuberosity This atrophy may be a later stage of the hyperplastic process described previously It appeared as if the reparative processes had ceased and most of the hypertrophied shredded ends of the torn fibers had been worn away (Figs 97 98 and 99) In such instances the damaged portion of the cuff passed under the coraco-acromial arch without interference In patients with partial or complete tears disappearance of pain may be accounted for by the removal of obstruction to free motion

Shredding and fraying of the fibers in the supraspinatus and the infraspinatus regions of the cuff was observed in many specimens Occasionally a depression in the cuff was discernible just proximal to its insertion into the humeral head (Fig 100) Alterations were most pronounced in and adjacent to this depression Thus, one was forced to assume that this area firmly abutted against the coraco-acromial ligament or the acromion when the arm was abducted or elevated Repeated trauma of this nature undoubtedly played a major role in the production of the alterations noted in the cuff

A few specimens disclosed lamination of both the deep and the superficial layers of the musculotendinous cuff parallel with the

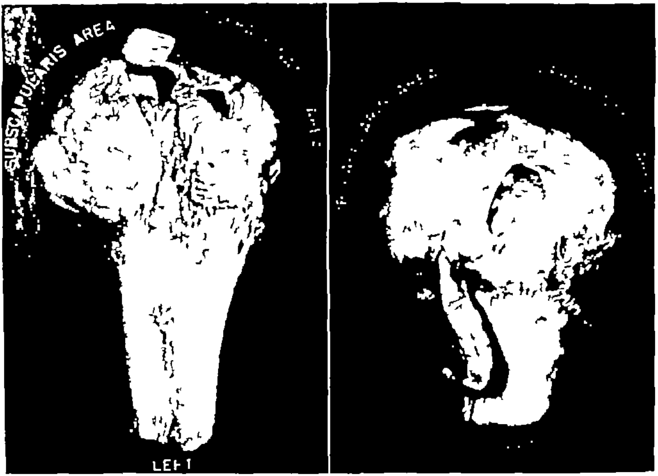
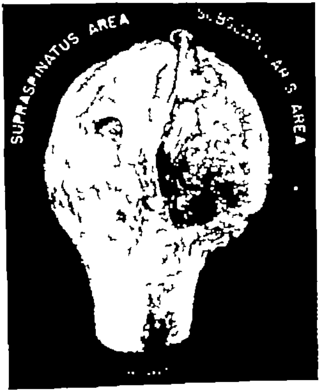


FIG 92 (*Top left*) Elongation of defect due to pull of fibers in direction of arrows. Bicipital groove has been opened for inspection Note the well formed supratubercular ridge over which the biceps tendon plays. (*Top right*) Slightly larger complete tear in supraspinatus region of cuff Edges are sharp smooth and thin Note how the defect tends to become elongated in the direction parallel with the muscle fibers. (*Bottom*) Small complete tear which still shows little evidence of elongation.



Elevation and abduction of the humerus of these shoulders disclosed an interesting observation which may have some bearing on the symptomatology of partial ruptures of the rotator cuff As the thickened portion of the cuff passed under the coraco-acromial ligament or the acromion a feeling of increased resistance and friction was noted and the thinned portion of the cuff buckled upon itself It is reasonable to assume that, as the hypertrophied portion of the cuff passes under the acromion or the coraco-acromial ligament the patient experiences varying degrees of pain dependent upon the amount of friction produced This pathologic alteration may be responsible also for the jog" and the crepitus (first recorded

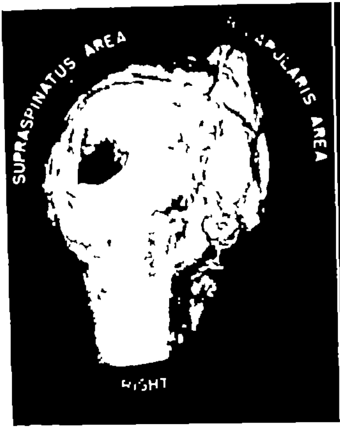


Fig 97 (*Left*) Advanced atrophy of the greater tuberosity There is a large defect in the head of the humerus. The bone around the defect is eburnated and polished. There is an extensive cuff tear involving the supraspinatus and the infraspinatus areas. The edges of the tear are thin and smooth.

Fig 98 (*Right*) Large complete tear extending across the bicipital groove involving the subscapularis tendon The biceps tendon is exposed and is frayed and thickened Tuberosities show pronounced recession and atrophy

supraspinatus muscle pulls the proximal torn fibers medially thereby producing an equilateral triangular defect (Figs 92, *top left* 94 and 96) These observations support McLaughlin s concept of the mechanism of the production of ruptures with retraction of the cuff but they fail to substantiate Codman s belief that the lateral ends of transverse tears are anchored while the center fibers retract medially

Larger lesions usually involved the entire width of the supraspinatus area and extended for varying distances into the infraspinatus portion of the cuff (Figs 94 and 96) Roughly the defect resembled an

Fig 99 Massive avulsion of the cuff with recession of the tuberosities erosion of the articular surface of the head of the humerus and formation of excrescences Only a few fibers of the subscapularis tendon remain intact The end of extracapsular portion of the biceps tendon has attained a bony attachment below the lesser tuberosity

FIG 95 (*Left*) An unusual type of complete tear completely circular and involving all the supraspinatus area and a part of infraspinatus area of the cuff Through the defect in the cuff can be seen the roughened pitted and irregular articular surface of the head of the humerus.

FIG 96 (*Right*) A triangular defect involving the supraspinatus and the infraspinatus regions of the cuff

joint cavity Fraying and shredding of the fibers were concomitant lesions in these specimens

Complete tears of the cuff varied in extent from small almost imperceptible openings to avulsion of the entire cuff (Figs 91 to 99) Thirteen specimens in this series revealed complete tears of some degree The supraspinatus area was involved in 46 1 per cent the supraspinatus and the infraspinatus areas, in 38 4 per cent the infraspinatus area alone in 0 7 per cent and the entire cuff in 0 7 per cent. The subscapularis area alone never was completely torn in 3 specimens it was implicated with tears in the supraspinatus and the infraspinatus tendons Small ruptures in the supraspinatus area of the cuff were located just proximal to the line of insertion of the tendon fibers into the tuberosity

Small tears failed to exhibit a specific configuration In general they were more or less irregular circular defects with scarred hypertrophied or thinned peripheral margins However many revealed a small longitudinal continuation of the defect parallel with the tendon fibers extending medially This longitudinal rent usually was observed arising from the anterior aspect of the defect Larger tears disclosed a more pronounced longitudinal rent making it clear that once a portion of the entire thickness of the cuff had pulled away at some point from its bony insertion it was subjected to opposing mechanical forces which split its fibers longitudinally

The infraspinatus and the teres minor muscles pull the posterior margin backward while the subscapularis muscle pulls the anterior margin forward at the same time the

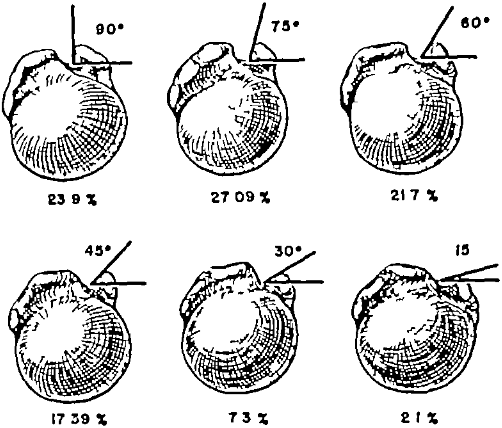


Fig 103 Drawing showing six variations and their incidences of the angle of medial wall of the intertubercular groove. (Redrawn with modification from Hitchcock and Bechtol J Bone & Joint Surg 30-A 263 273)

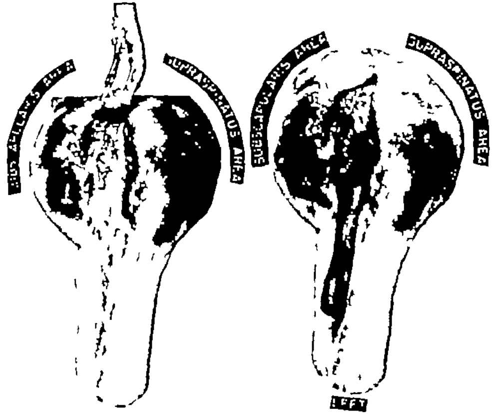


Fig 104 (*Left*) Note defect in frayed biceps tendon and spur in the floor of the bicipital groove. (*Right*) When the tendon is in its normal position the defect in its substance fits snugly around the bony spur

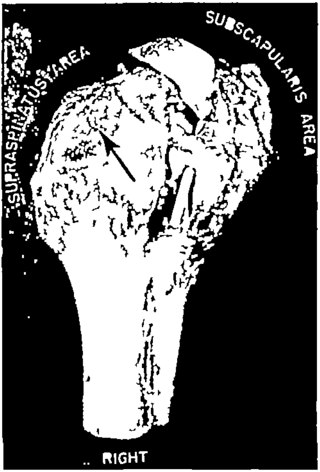


FIG 100 Note flattened roughened surface of the musculotendinous cuff over the greater tuberosity This area impinged against the acromion upon abduction of the arm. A marker has been passed beneath a defect in the attachment of the subscapularis tendon. The tissues above the marker form a fascial sling for the biceps tendon which no longer lies in the intertubercular sulcus.

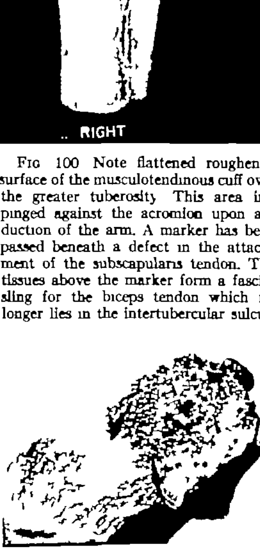


FIG 101 Undersurface of acromion process of specimen shown in Figure 99 The peripheral margin reveals advanced new bone formation The undersurface of the acromion is eburnated and highly polished, resulting from constant contact with articular surface of the head of the humerus

FIG 102 Schematic drawing showing a supratubercular ridge which may facilitate displacement of biceps tendon out of the intertubercular sulcus.

equilateral triangle with its base on the tuberosity No vestige of the distal end of the cuff was demonstrable in these specimens Bony excrescences over the tuberosities were encountered frequently In some it became apparent that these hypertrophic lesions impinged upon the acromion during abduction of the arm Evidence of such trauma was noted on the edge of the acromion by the presence of both bony spurs and roughening

Several specimens with large defects in the cuff revealed advanced recession and atrophy of the tuberosities as if they were being leveled off gradually (Figs 93 94 97 98 and 99) Two specimens revealed that the tear extended across the bicipital groove and involved the upper half of the subscapularis tendon (Figs 93 and 98) Another disclosed a massive avulsion of the cuff (Fig 99) The humeral head which showed advanced hypertrophic changes lay beneath the acromion which exhibited a dense

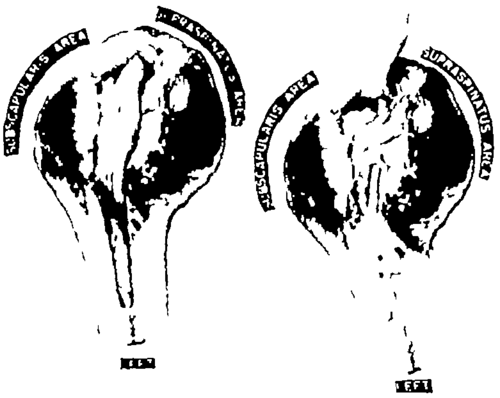


Fig 105 (*Left*) Biceps tendon lies to inside of the lesser tuber osity (*Right*) Note the reduction in the height of the lesser tu berosity also a well formed fascial sling extending from the fibrous capsule to the remainder of the lesser tuberosity The undersurface of the biceps tendon reveals advanced degenerative changes.

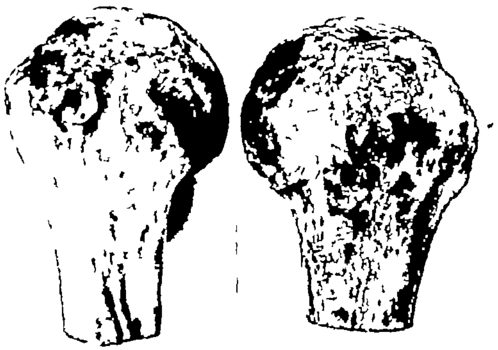


Fig 106 (*Left*) Well formed bony excrescences over both tuber osities. The intertubercular sulcus is narrowed and the head of the humerus proximal to the sulcus is flattened and eburnated The biceps tendon of this specimen was thickened frayed and shredded (*Right*) Note complete atrophy and recession of tuberosities oblit eration of intertubercular sulcus, excrescences in bicipital groove and eburnation of the head of the humerus, anterior superior and posterior to the bicipital groove. The biceps tendon was thinned frayed and shredded

eburnated and highly polished inferior surface (Fig 101)

Tuberosities and Bicipital Groove

Irregular new bone formation, in varying degrees, over the tips of the tuberosities was the most outstanding pathologic alteration discernible in specimens after the fifth decade This, together with thinning or complete rupture of the cuff in the supraspinatus area was responsible for the formation of a depression (sometimes palpable through the deltoid) in the floor of the subacromial bursa Codman pointed out

> The tuberosity forms a distinct eminence and may cause a jog and friction as it passes upward under the acromion. The result is a stimulation of the bone cells in the tuberosity and irregular excrescences formed at the region where undue friction occurs This new formed bone is very spongy and probably later atrophies since one finds that complete recession of the whole tuberosity has taken place in the very old cases.
>
> Atrophy of the tendon without actual rupture might cause enough irregularity in the base of the bursa to begin a little irritation A vicious circle of atrophy of tendon inflammation of tuberosity osteitis excrescences greater jog and greater friction greater atrophy etc. might be established. At the same time hypertrophic changes in the acromial edge are stimulated

There is complete agreement with this cycle of events and subsequent changes in the tuberosities

As the result of these bony lesions alterations in the configuration of the bicipital groove were demonstrable Not infrequently in specimens exhibiting marked hypertrophic new bone formation over and around the tuberosities the bicipital sulcus was narrowed and occasionally obliterated by these lesions Bony spurs often were observed on the inner and the outer surfaces of the bicipital sulcus being more common in the intertubercular portion of the groove It becomes apparent that such alterations necessarily must interfere with normal excursion of the humeral head on the biceps tendon This fact was substantiated by the severe degenerative changes observed in the biceps tendons (Fig 104)

In specimens with marked atrophy and recession of the tuberosities, the intertubercular portion of the bicipital sulcus was worn away completely in many instances The biceps tendon, which had become displaced from the sulcus now occupied a position on the inner aspect of the remains of the lesser tuberosity It was supported by a fascial sling such as described by Meyer (Fig 105) Six of the specimens studied in the first part of this chapter and 4 of those studied in the second disclosed complete absence of the intracapsular portions of the biceps tendons. The extracapsular ends were found attached to the humeral shafts below the lesser tuberosities (Fig 133)

In this investigation the bicipital groove exhibited many significant variations Meyer (1928) first described a supratubercular ridge which is a ridge of bone continuous with the medial wall of the groove and extends proximally toward the articular margin of the humeral head (Fig 102) *Its size* and configuration vary considerably In this study it was a pronounced structure in ?3.8 per cent of the humeri moderately developed in 31 5 per cent and absent in 43 4 per cent Hitchcock and Bechtol found the ridge markedly developed in 8 per cent moderately developed in 59 per cent and absent in 33 per cent This supratubercular ridge as pointed out by Meyer (1928) favors dislocation of the bicipital tendon by levering it out of the proximal portion of the groove Supratubercular ridges, sufficiently high to displace the tendon against the transverse humeral ligament are responsible for repeated trauma inflicted to the tendon and the tendon sheath during joint motion Hitchcock and Bechtol (1938) noted that the height of the groove depended directly upon the obliquity of its medial wall They found the angle of the medial wall to be 90 in 10 per cent of their humeri 75 in 35 per cent 60 in 34 per cent 45 in 13 per cent 30° in 6 per cent and 15° in 2 per cent This investigation

revealed the angle of the medial wall to be 90° in 23 9 per cent, 75 in 27 09 per cent, 60° in 21 7 per cent 45° in 17.3 per cent, 30 in 7.3 per cent, and 15° in 2 1 per cent (Fig 103) It was further observed that the base of the supratubercular ridge also was a factor in diminishing the depth of the groove Nine per cent of the humeri with a supratubercular ridge disclosed this variation In these specimens, the base of the ridge was unusually broad and continued across the floor of the groove toward its lateral wall (Fig 102) Bony spurs were observed on the medial wall in 9 per cent of the specimens, on the lateral wall in 13 per cent, and on both walls in 7.3 per cent Spur formation undoubtedly follows inflammatory changes in the groove such bony structures render the biceps tendon vulnerable to repeated trauma and attritional alterations (Figs 104 106, 107, *right* and 108 *right*)

It was interesting to note that the height of the lesser tuberosity was reduced markedly in many specimens of the later decades

In the light of the observations recorded in this study, it becomes apparent that physiologic aging plays a major role in the production of degenerative alterations in the musculotendinous cuff However such factors as occupation excessive usage debilitating disease and repeated minor trauma in a measure also must be considered as responsible. Study of the cases in the second part of this chapter has revealed that many of the above-recorded lesions particularly partial ruptures of the cuff (rim rents) and complete ruptures in some instances are compatible with normal joint function without pain. We are forced to believe that symptoms and disability often are not caused by the lesion per se but by the associated sequelae which interfere with normal mechanics of shoulder joint function

Summary

1 Progressive degenerative alterations are noted in the articular cartilage of the glenoid cavity as early as the second decennium In the early decades, these changes consisted of unevenness, fibrillations and furrows Pitting erosions and marginal bone proliferations occurred later The central depressed area in the center of the comma s head we believed to be an area of greater contact than the surrounding cartilage These progressive changes reached their height in the sixth decennium

2 The labrum glenoidale because of its anatomic position surrounding the glenoid cavity and because of its intimate relationship to the biceps tendon and the synovial ligaments is subjected to stress and strain during normal shoulder function Hence degenerative changes manifest themselves rather early and become more pronounced and frequent with each subsequent decade These alterations consist of labral detachments, thinning, scalloping undulations and synovial tabs and fringes Labral detachments may be interpreted erroneously as the result of local trauma and as the underlying pathology of recurrent dislocations of the shoulder The above findings fail to substantiate Bankart s contention that labral detachment is the causative factor in producing recurrent dislocations of the shoulder, and also provide an explanation for the frequent failures of the various suspension operations (such as the Nicola procedure) utilized to stabilize recurrent dislocating shoulders

3 No significant changes were noted relative to the biceps tendon until the fifth decade These consisted of thickening, widening, and shredding becoming more pronounced with each subsequent age group It is of interest to note that these changes occurred concurrently with the appearance of degenerative lesions in the musculotendinous cuff It is reasonable to assume therefore, that as degenerative lesions begin to manifest themselves in the musculotendinous capsule the biceps tendon is forced to function as one of the main supports of the upper extremity Hence it is subjected to great attritional forces which

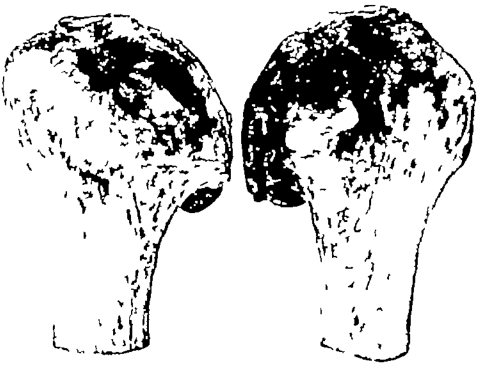


Fig 107 (*Left*) Posterior view A large defect in the posterolateral aspect of the head of the humerus with formation of numerous excrescences around the defect. (*Right*) Anterior view Intertubercular groove is narrowed by excrescences. In this instance the biceps tendon was frayed and attenuated. Note profound degenerative changes and roughened bone in humeral head proximal to the inter tubercular groove Also osseous and cartilaginous changes due to an old compression fracture through the anatomic neck of the humerus.

Fig 108 (*Left*) Posterior aspect Complete atrophy of the greater tuberosity and new bone formation on the posterior aspect of the shaft of the humerus below the level of the neck. (*Right*) Anterior aspect. Bicipital groove is completely obliterated by new bone formation. In this specimen no intracapsular portion of the biceps tendon was found. The proximal end of the extracapsular portion was buried in the osseous tissue obliterating the groove.

revealed the angle of the medial wall to be 90° in 23 9 per cent, 75° in 27 09 per cent, 60° in 21 7 per cent, 45° in 17.3 per cent, 30° in 7.3 per cent, and 15° in 2 1 per cent (Fig 103) It was further observed that the base of the supratubercular ridge also was a factor in diminishing the depth of the groove Nine per cent of the humeri with a supratubercular ridge disclosed this variation In these specimens, the base of the ridge was unusually broad and continued across the floor of the groove toward its lateral wall (Fig 102) Bony spurs were observed on the medial wall in 9 per cent of the specimens, on the lateral wall in 13 per cent and on both walls in 7.3 per cent Spur formation undoubtedly follows inflammatory changes in the groove such bony structures render the biceps tendon vulnerable to repeated trauma and attritional alterations (Figs 104 106, 107, *right* and 108 *right*)

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In the light of the observations recorded in this study it becomes apparent that physiologic aging plays a major role in the production of degenerative alterations in the musculotendinous cuff However, such factors as occupation excessive usage, debilitating disease and repeated minor trauma, in a measure, also must be considered as responsible Study of the cases in the second part of this chapter has revealed that many of the above recorded lesions particularly partial ruptures of the cuff (rim rents) and complete ruptures in some instances are compatible with normal joint function without pain We are forced to believe that symptoms and disability often are not caused by the lesion per se but by the associated sequelae which interfere with normal mechanics of shoulder joint function

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FIG 109 D A. male white age 43 Right shoulder A finished specimen which has been mounted on a circular glass rod frame so that the synovial side of the musculotendinous cuff the biceps tendon and the articular surfaces of the head of the humerus are clearly visualized.

are responsible for the various alterations in the tendon

4 Variations as to size location and number of the synovial ligaments and synovial recesses are numerous These variations may be developmental the result of synovial changes in the subscapularis area or alterations in the biceps tendon and the labrum The clinical significance of these findings is obvious when a shoulder joint is explored to correct the causative pathology responsible for recurrent dislocations. One may readily misinterpret a large synovial recess for a rent in the capsule and a middle glenohumeral ligament as a detached and displaced labrum

5 Changes in the musculotendinous capsule first appeared in the fifth decade These changes varied from minor incomplete tears to complete tears in one or all of the rotator tendons In the presence of a tear the synovial lining formed a falciform ligament across the defect as if attempting to repair it. The study of the inside of the glenohumeral joint revealed 24 per cent supraspinatus tears and 41 per cent subscapularis tears, while that on the outside of the cuff disclosed complete tears in only 13 per cent of the specimens Such lesions were more common and of greater severity in the later decenniums, leading one to believe that they are degenerative lesions due to wear and tear and to aging"

6 Lesions of the inside of the musculotendinous cuff are encountered more frequently and of greater severity than those on the outside of the cuff

7 The biceps tendon exhibits degenerative alterations which progress in gradient in each successive decade, beginning with the fifth. These lesions are associated with aging and also are caused by the changes in the bony configuration of the bicipital groove produced by excrescences spurs and new bone formation.

LESIONS OF THE SHOULDER COMPATIBLE WITH GOOD FUNCTION

INTRODUCTION

The investigation recorded in the first part of this chapter brought to light many significant observations relative to the degenerative lesions manifested in the biceps tendon the labrum glenoidale and the musculotendinous cuff in different age groups Unfortunately the gross study was conducted on shoulder joints of individuals on whom no histories were available prior to death while the microscopic study was made on shoulders obtained from individuals on whom histories were obtained and examinations made of the shoulders prior to death, but no attempt was made to correlate these clinical data with the observations noted other than that these patients had sustained no severe injuries during their lifetime Therefore one was unable to eval

uate the true clinical significance of these observations However, it was felt that the findings were of sufficient importance to pursue the study further hence the following investigation was undertaken on a series of shoulder joints obtained from individuals postmortem on whom sufficient clinical data were obtained prior to death to permit correlation of the abnormalities noted in the component structures of the shoulder joint with the functional capacity of the joint It was of great significance to observe the pronounced severity of degenerative lesions in the musculotendinous cuffs and the biceps tendons that is compatible with good function This study demonstrated further the sequence and the manner in which the degenerative alterations occurred Finally one was made aware that our present-day concept of the management of many lesions of the shoulder needs further investigation and revision

Materials and Methods

Ninety six shoulder joints were obtained postmortem from 50 individuals A clinical

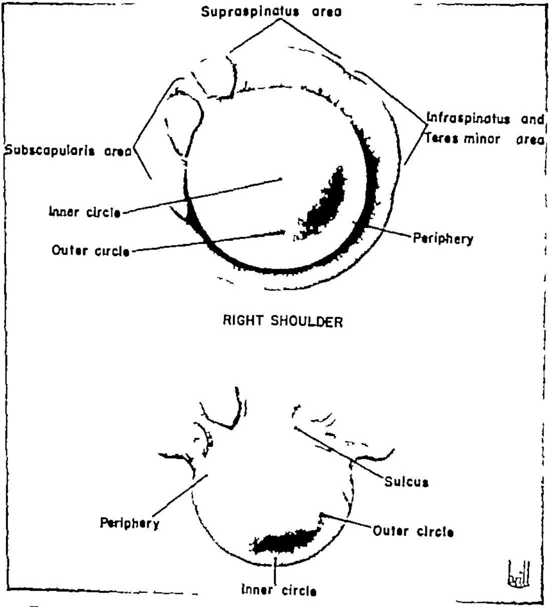

FIG 110 Schematic drawing of finished mounted specimen showing division of articular cartilage into the inner circle the outer circle and periphery the sulcus which is produced by recession of the cuff, and the designated areas of the musculotendinous cuff

FIG 109 D A. male white age 43 Right shoulder A finished specimen which has been mounted on a circular glass rod frame so that the synovial side of the musculotendinous cuff the biceps tendon and the articular surfaces of the head of the humerus are clearly visualized.

are responsible for the various alterations in the tendon.

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INTRODUCTION

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history was obtained and an examination of the shoulders made and recorded on these individuals prior to their deaths Only shoulder joints of patients who believed that they possessed normal shoulders, who were unaware of any disability and disclosed no shoulder dysfunction by examination were selected for this study At this place it must be pointed out that the above clinical data were obtained from individuals who were mentally alert and competent to give accurate information many of these patients were kept under observation for many weeks before death occurred Moreover, the patients who provided the specimens for study formed a small group of the patients examined for this investigation because many of the individuals studied were fortunate enough to recover from their malady and to be discharged from the hospital In only two instances was it necessary to obtain the clinical data desired from relatives of the deceased Most of these individuals gave a history that at some time in their lives they had some temporary disability of the shoulder none however, had any severe traumatic lesions to the shoulder followed by marked dysfunction One gave a history which was consistent with that of a frozen shoulder on both sides (Fig 133) Only 2 patients in this group had some pain on motion for 6 months prior to death movements in the shoulder, however were not impaired There were 36 males and 14 females 48 right and 48 left shoulders the age ranged from 18 to 74 years Roentgenograms of all shoulders were made, the specimens were then mounted (Fig 109) and studied

For the purpose of study and presentation the articular surface of the head of the humerus was divided into three parts the central area was designated the inner circle the outer area, the outer circle and the margin of the articular cartilage the periphery The interval between the periphery and the inner surface of the musculotendinous cuff was designated the sulcus, while the musculotendinous cuff was divided into

FIG. 113 R. C, female, white, age 52 Left shoulder This is the only specimen of this series that revealed an erosion in the inner circle. Note the depression in the superior aspect of the head in that region of the periphery adjacent to the supraspinatus tendon Also the extensive, incomplete tear which implicates all the supraspinatus and infraspinatus regions of the cuff The humeral defect may be the result of a growth defect or unrecognized trauma.

the subscapularis the supraspinatus and the infraspinatus and the teres minor areas (Fig 110)

Observations Referable to the Articular Cartilage of the Head of the Humerus

It was interesting to note that alterations in the articular cartilage of the head of the humerus were never extensive even in the very late decades of life They did not parallel the changes observed in the articular cartilage of the glenoid cavities of representative specimens of the same age period (Fig 111) For example the humeral head in Figure 111 *left* discloses only minimal changes when compared with the glenoid cavity of the same shoulder joint shown in Figure 111, *right* As a rule, the

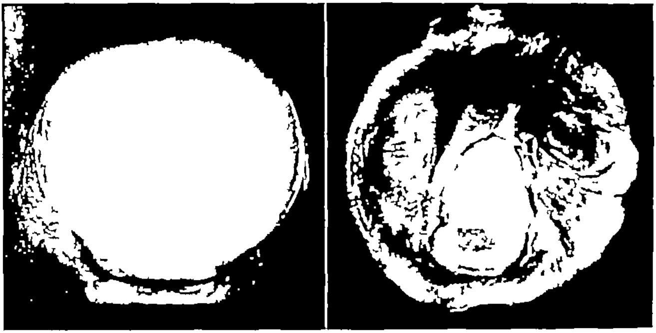


FIG 111 (*Left*) Articular surface of the head of the humerus exhibits only minimal degenerative alterations as compared with those noted in the glenoid fossa of the same shoulder (*right*) This was true of most of the shoulder joints in this series. (*Right*) Degenerative changes in the articular cartilage of the glenoid cavity are more pronounced than those in the head of the humerus of the same shoulder joint (*left*)

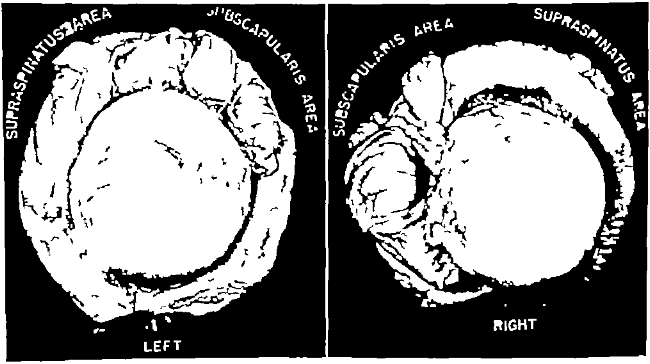
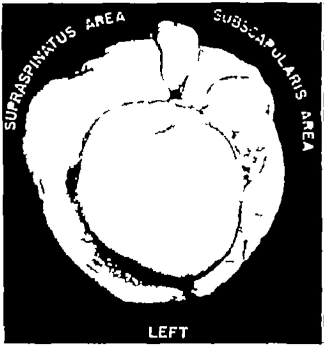


FIG 112 (*Left*) W S, male white age 67 Left shoulder Note the increase in gradient of degenerative lesions in the outer circle over those in the inner circle This ratio was a constant feature in the great majority of shoulders exhibiting alterations in the articular cartilage of the head of the humerus. (*Right*) Right shoulder of the same patient. As in the illustration at the left there are noted more pronounced degenerative lesions in the outer circle and periphery of the articular surface of the head of the humerus than in the inner circle. Also observe the extensive incomplete tear in the subscapularis portions of the cuff and the recession of the torn cuff from the periphery of the articular margin.

FIG 118 (*Left*) D F male white age 55 Right shoulder There are ad vanced degenerative lesions implicating the whole synovial side of the musculotendinous cuff, particularly in the supra spinatus and infraspinatus areas. The cuff has receded a considerable distance from the margin of the articular carti lage forming a wide sulcus (*Right*) Same shoulder, viewing the cuff from the outside Note that it is impossible to evaluate the severity of the lesions on the inside of the cuff by the appearance of its outer surface

inner circle exhibited the least severe alter ations while the most profound lesions were found along the periphery of the articular cartilage. The outer circle in most instances disclosed degenerative changes of greater severity than those noted in the articular cartilage of the inner circle The alterations in the inner and the outer circles comprise thinning fibrillation, pitting and erosion of the articular cartilage Along the periphery the findings consist of pitting and erosions of the cartilage and formation of bony spurs and excrescences (Figs 112 and 113) Only one specimen of the series (a specimen in the sixth decade) disclosed a true erosion of the articular cartilage in the inner circle (Fig 113) One specimen (Fig 115) of the sixth decade exhibited maximum alterations in articular cartilage of the inner and the outer circles encountered in this series Al though there was a gradual rise in gradient of the degenerative lesions in each succes sive decade starting with the third the changes never reached such profound proportions as they did in the glenoid cavities nor did they parallel the extensive changes noted in the musculotendinous cuff (Fig 116) This observation points out that development of degenerative changes in the soft tissue components of joints is not sec ondary to abnormalities in the cartilaginous and osseous tissues During joint motion only a small portion of the articular surface of the large head of the humerus is in con tact with that of the small glenoid cavity It becomes apparent that contact areas in the glenoid cavity are subjected to more wear and tear than contact areas in the humeral head This readily explains the discrepancies in the severity of the changes in the articular surfaces of the humeral head and glenoid fossa



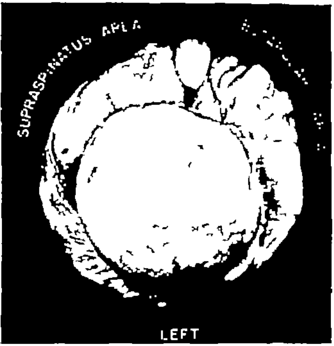


FIG 114 (*Left*) R G male white, age 32 Left shoulder Note indentation in superior portion of the head of the humerus also the irregularity of the entire head. The defect may be the result of unrecognized trauma or a growth defect.

FIG 115 (*Right*) J P., male white age 57 Left shoulder This specimen exhibits the most pronounced degenerative lesions in the articular cartilage of the head of the humerus. Those in the outer circle and the periphery disclose greater severity than those in the inner circle.

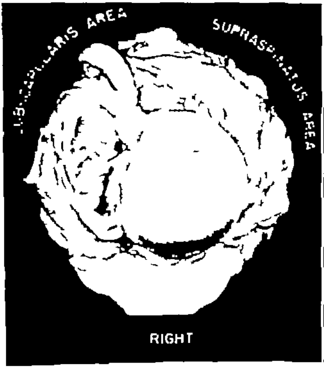


FIG 116 (*Left*) R. M female white age 55 Right shoulder Degenerative changes in the articular cartilage of the head of the humerus do not parallel those in musculotendinous cuff Note in this specimen the severe alterations in the subscapularis regions of the cuff and only minimal lesions in the humeral head

FIG 117 (*Right*) D A. male white age 23 Left shoulder This specimen discloses no macroscopic evidence of degenerative changes. Note that the musculotendinous cuff with its synovial lining is in close proximity to the margin of the articular cartilage Nowhere is there any recession of the cuff fibers.

Fig 118 (*Left*) D F male, white, age 55 Right shoulder There are advanced degenerative lesions implicating the whole synovial side of the musculotendinous cuff, particularly in the supraspinatus and infraspinatus areas. The cuff has receded a considerable distance from the margin of the articular cartilage, forming a wide sulcus. (*Right*) Same shoulder, viewing the cuff from the outside. Note that it is impossible to evaluate the severity of the lesions on the inside of the cuff by the appearance of its outer surface.

inner circle exhibited the least severe alterations, while the most profound lesions were found along the periphery of the articular cartilage. The outer circle in most instances disclosed degenerative changes of greater severity than those noted in the articular cartilage of the inner circle The alterations in the inner and the outer circles comprise thinning fibrillation pitting and erosion of the articular cartilage Along the periphery the findings consist of pitting and erosions of the cartilage and formation of bony spurs and excrescences (Figs 112 and 113) Only one specimen of the series (a specimen in the sixth decade) disclosed a true erosion of the articular cartilage in the inner circle (Fig 113) One specimen (Fig 115) of the sixth decade exhibited maximum alterations in articular cartilage of the inner and the outer circles encountered in this series Although there was a gradual rise in gradient of the degenerative lesions in each successive decade starting with the third the changes never reached such profound proportions as they did in the glenoid cavities, nor did they parallel the extensive changes noted in the musculotendinous cuff (Fig 116) This observation points out that development of degenerative changes in the soft tissue components of joints is not secondary to abnormalities in the cartilaginous and osseous tissues During joint motion only a small portion of the articular surface of the large head of the humerus is in contact with that of the small glenoid cavity It becomes apparent that contact areas in the glenoid cavity are subjected to more wear and tear than contact areas in the humeral head This readily explains the discrepancies in the severity of the changes in the articular surfaces of the humeral head and glenoid fossa

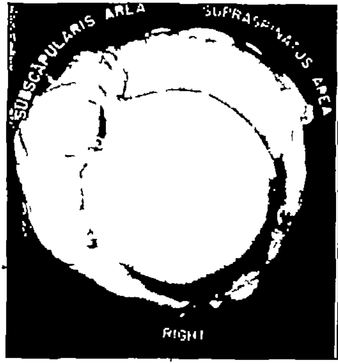


FIG 119 (*Left*) A. G, male, white age 47 Right shoulder Large incomplete tear exists in the subscapularis tendon. Note the thickened synovial membrane distal to the defect in the cuff this is nature s method of trying to limit the progress of the tear, designated by Codman the falciform ligament.

FIG 120 (*Right*) J M male, white, age 54 Right shoulder A moderate size incomplete tear in the supraspinatus and infraspinatus areas of the cuff

SULCUS

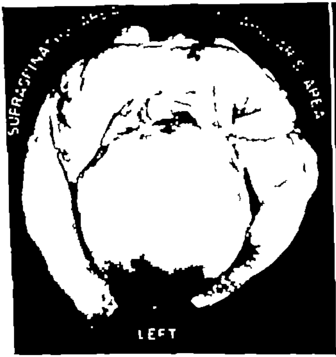
In shoulders of infants and of individuals in the early decades the rotator cuff in the supraspinatus the subscapularis and the infraspinatus and the teres minor areas filled completely the interval between the tuberosities and the periphery of the articular cartilage This is demonstrated in Figure 117 a specimen of the third decade In the fourth decade several shoulders revealed a gradual tearing away of the cuff from the periphery This change was observed more frequently in the supraspinatus area than the other portions of the musculotendinous cuff Pitting bony spurs and excrescences were common findings in the sulcus. The afore mentioned alterations increased in intensity in each subsequent decade In some specimens the periphery revealed subchondral new bone formation its articular edge was raised thickened irregular and studded with cartilaginous nodules in some instances The degree of severity of the degenerative lesions in the sulcus was in direct proportion to those in the adjacent musculotendinous cuff As more and more fibers tore away the insertion of the cuff became thinner the width of the sulcus was dependent upon the extent of the recession of the cuff from its bony insertion (Fig 118 *left*)

SYNOVIAL MEMBRANE AND MUSCULOTENDINOUS CUFF

Macroscopic synovial alterations were first discernible in the second decade. They comprised shredding fraying tabs and villous formation. A gradual progression in severity was demonstrable in each successive age period however the lesions paralleled those noted in the musculotendinous cuff Specimens of the sixth decade revealed lesions of the greatest severity in the synovial membrane

Tears on the synovial side of the musculotendinous cuff were first observed in the

FIG 121 (*Left*) T C, male white, age 43 Right shoulder Large incomplete tear in supraspinatus area of the cuff Note the recession of the cuff fibers and thickening of the torn fibers. (*Right*) Left shoulder Large incomplete tear in supraspinatus and infraspinatus portion of the cuff, with recession of cuff and marked thickening of the torn fibers.



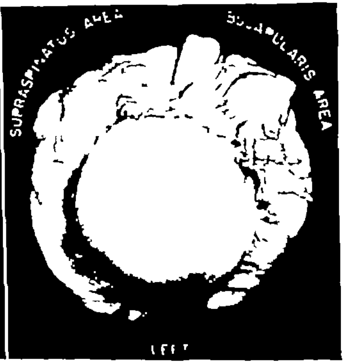


FIG 122 (*Left*) J M male, white age 54 Left shoulder Small incomplete tear in the supraspinatus region of the cuff

FIG 123 (*Right*) S R. male white age 55 Left shoulder Advanced degenerative lesions of the synovialis lining the musculotendinous cuff and incomplete tears of the subscapularis, the supraspinatus and the infraspinatus areas. Note the thickened, hyperplastic torn fibers and the minimal changes in the articular cartilage of the head of the humerus compared with the extensive alterations in the cuff

FIG 124 (*Left*) R. C female white age 62 Right shoulder Large incomplete tear exists in the supraspinatus and a small part of the infraspinatus regions of the cuff Note once more the marked hypertrophy of the torn fibers

FIG 125 (*Right*) J C., male colored age 54 Right shoulder There is a moderate incomplete tear in the supraspinatus region of the cuff and also considerable degenerative changes in the synovialis of this area and in the synovial membrane lining the subscapularis area of the cuff

fifth decennium Like other degenerative lesions these showed a gradual rise in gradient in each successive decade the most severe abnormalities were encountered in the sixth and the seventh decades In this series there were found 20 subscapularis tears (20.8 per cent) and 35 supraspinatus and infraspinatus tears (37.3 per cent) These findings differ from those noted in the discussion on the glenoid side of the glenohumeral joint in which the incidence of subscapularis tears was greater than that of supraspinatus tears. As a rule tears of the supraspinatus areas extended into the infraspinatus region of the cuff This feature is not appreciated when only the outer side of the cuff is inspected The appearance of the outer side of the musculotendinous cuff gives an erroneous impression of the extent of the degenerative lesions existing in the structure Only by visualizing the inside of the cuff can one determine the severity of the changes (Fig 118) This is particularly true of complete tears of the cuff There were nine complete tears in this group of specimens

It was interesting to note the types and the extent of incomplete tears that are compatible with normal function they varied from small tears in and shredding of the cuff to extensive areas of tearing fraying and thinning of the subscapularis and the supraspinatus and infraspinatus insertion of the rotator cuff Pronounced thickening and hypertrophy were characteristic features of the torn cuff fibers (Figs. 119 to 128 inclusive)

Two shoulders (Fig 128) were obtained from a male 59 years of age This individual was unaware of any shoulder dysfunction at the time of examination except for some restriction of external rotation no other abnormalities were noted clinically in either shoulder

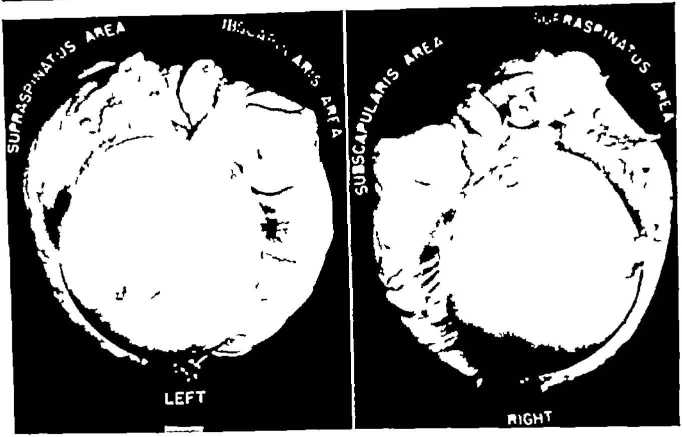


Fig 126 (*Left*) C D female colored age 56 Left shoulder Observe the marked fraying, tearing and shredding of the fibers of the musculotendinous cuff in the supraspinatus and part of infraspinatus regions of the cuff Again note the marked hypertrophy of the torn fibers. (*Right*) Right shoulder There is considerable tearing of the fibers of the entire supraspinatus and infraspinatus regions of cuff, also marked hypertrophy of the torn fibers and recession of cuff from the periphery of the articular margin in the affected region.

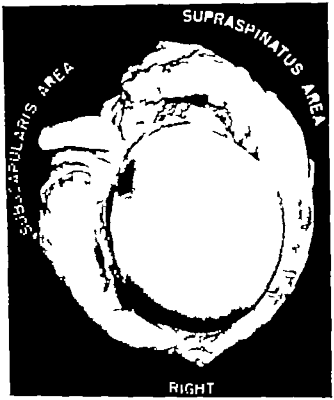


Fig 127 J S male white age 54 Right shoulder An unusually large tear exists implicating the entire supraspinatus and a portion of the infraspinatus region of the cuff There is unusual hypertrophy and thickening of the torn fibers and marked recession and thinning of the remaining intact fibers of the cuff

The right shoulder (Fig 128 *right*) revealed advanced degenerative changes of the synovial membrane The alterations comprised tabs fraying hyperplasia and villous formation It exhibited an extensive incomplete tear in the musculotendinous cuff including all the supraspinatus and part of the infraspinatus tendon whereas the articular cartilage of the humeral head showed only minimal lesions

All the above changes were more pronounced in the left shoulder (Fig 128 *left*) The incomplete cuff tear extended from the middle of the infraspinatus tendon to the

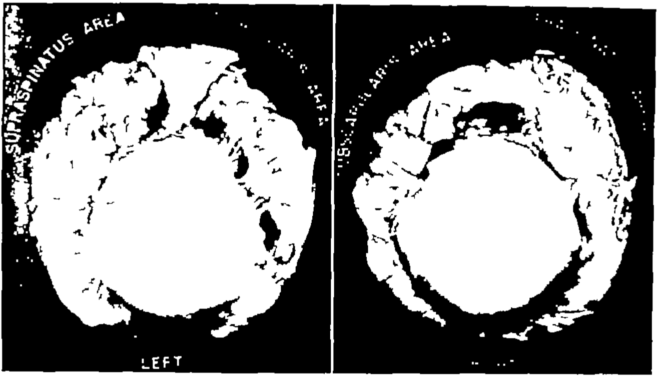


Fig. 128 (*Left*) J S male white age 59 Left shoulder Profound degenerative changes involving all of the synovialis. Note the marked tearing away of the entire musculotendinous cuff from the periphery of the articular margin. Only a few strands of tissue remain intact in the subscapularis area. Observe also the marked hypertrophy of the torn fibers, the deep sulcus, and the widening and thickening of the biceps tendon. On either side of the exit of the tendon the capsular fibers have torn away from the posterior and anterior lips of the intertubercular sulcus so that the exit of the tendon is widened (*Right*) Right shoulder There are demonstrable advanced degenerative changes of the synovialis in the region of the supraspinatus and infraspinatus regions and to a lesser degree in the subscapularis region of the cuff Note the recession of the cuff in the supraspinatus area forming a broad sulcus. There is also considerable irregularity and new bone formation in the form of excrescences in the floor of the sulcus. This is an extensive incomplete tear

lower border of the subscapularis tendon Several ribbonlike strands of tendon fibers in the subscapularis region of the cuff still remained attached to the humeral head Advanced lesions were also discernible in the biceps tendon particularly the intracapsular portion of the tendon it was frayed thickened and covered with numerous villi Although the inner and the outer circles of the head of the humerus showed minimal lesions the periphery adjacent to the degenerated cuff was raised and irregular The sulcus was widened and studded with numerous excrescences of varying sizes

Not knowing that these specimens were obtained from individuals who were unaware of any disorders of their shoulder joint from a clinical viewpoint one is apt to interpret these findings as responsible for the painful syndrome so commonly encountered in individuals past middle life. Many workers are of the opinion that partial tears and tendinitis are responsible for symptoms of internal derangements such as torn degenerated menisci produce in the knee joint. That such a syndrome exists in the shoulder joint is common knowledge but in the light of the above observations it is reasonable to conclude that other factors must be present in addition to incomplete tears in the cuff before dysfunction of the scapulohumeral joint is manifested One is led to believe that pain is not the result of the incomplete tear of the cuff per se but is due

Fig 129 (*Left*) A R., male, white age 62 Right shoulder A massive com plete tear exists involving the whole supraspinatus and a large portion of the infraspinatus tendon Note the marked fraying, shredding and degenerative changes in the remaining portion of the cuff (*Right*) The synovial side of the specimen shown at left. Observe the thickness of the biceps tendon which has been completely displaced from the intertubercular groove and lies on a fascial sling formed by the upper border of the intact subscapularis tendon There is also evidence of marked degenerative changes in the synovial membrane of the entire cuff Such an arrangement as is shown by the biceps tendon permits it a free excursion of motion in the new wide tunnel

to impingement of the overlying sensitive subacromial bursa against the coraco-acromial arch during elevation of the arm Marked thickening and hyperplasia of the torn fibers of the cuff forces the bursal sac against the acromion and the coraco-acromial ligament when the arm is raised above the horizontal position It is apparent that repeated trauma to the bursa may give rise to the so-called supraspinatus or painful arc syndrome This explains why excision of the acromion or the bursa or both results in a cure of the symptom complex

Even more significant than the incom plete tears were the complete tears of the musculotendinous cuff As previously re-corded there were 9 complete tears, ranging in size from 1 centimeter to massive avul sion of the cuff Six shoulders disclosed only a small portion of the subscapularis tendon and of the infraspinatus and the teres minor tendons to be intact yet these individuals possessed no impairment of shoulder func tion Two of these individuals complained of some pain in the right shoulder during motion for approximately six months prior to death but function was not impaired Figure 129 shows a right shoulder joint ob-tained from a male 62 years old a large defect exists in the cuff The tear includes all of the supraspinatus and a large portion of the infraspinatus tendon The edges of the tear have retracted mesially posteriorly and anteriorly exposing a large segment of the head In accordance with our present day concept of the extent of a tear in the cuff which is compatible with good function, one is apt to believe that such a tear as this

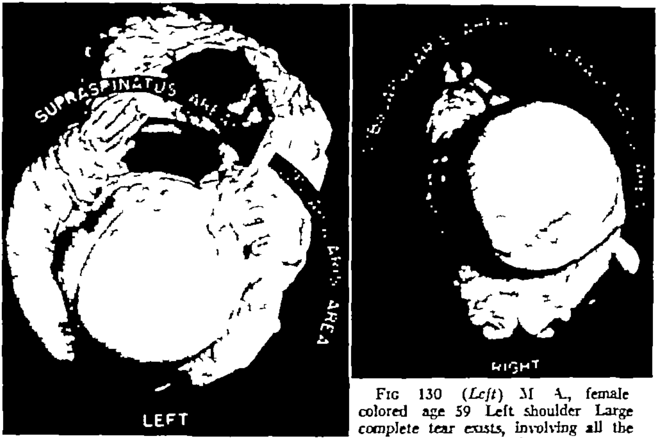


Fig 130 (*Left*) M A., female colored age 59 Left shoulder Large *complete tear exists*, involving all the supraspinatus and infraspinatus portions of the cuff Only the teres minor tendon remains intact. There is also evidence of advanced degenerative changes in the subscapularis region of the musculotendinous cuff. Both tuberosities have been leveled off In this specimen the subacromial bursa has been distended and fixed in order to exhibit marked widening and hypertrophy of its walls. (*Right*) Right shoulder Note the extensive complete tear involving a portion of the subscapularis *tendons* and even a portion of the teres minor tendon. In spite of extensive defect in the cuff this patient was able to elevate her arm freely both in the frontal *and the coronal planes.*

would result in complete loss of abduction power in the shoulder yet the individual had no difficulty in abducting the arm.

More revealing are the two specimens depicted in Figure 130 They were obtained from the shoulders of a female 59 years old The left shoulder (Fig 130 *left*) discloses an extensive cuff tear extending from the teres minor muscle above to the upper one third of the subscapularis below Also the *synovial lining of the remaining cuff exhibits* profound degenerative changes Note that both the tuberosities have been leveled off so that the upper end of the humerus forms almost a complete smooth sphere On the other hand the articular cartilage of the head of the humerus shows relatively minimal degenerative changes In Figure 130 *left* the bursa has been distended and fixed so as to show its thickened walls and its increase in all dimensions

More *extensive changes* in the musculotendinous cuff were observed in the right shoulder (Fig. 130 *right*) Only the tendon of the teres minor and approximately half of the subscapularis tendon remain attached to the head of the humerus As in the left shoulder complete recession of both tuberosities occurred while the articular car*tilage of the head of the humerus exhibits* minimal degenerative changes Again one would assume that in the face of such extensive pathologic alterations in the stabilizing apparatus of the scapulohumeral joint, dysfunction of the joint must exist. On the

Fig 131 (*Left*) M W, female, white, age 63 Left shoulder Complete absence of cuff substance in the supraspinatus and infraspinatus areas Only the teres minor tendon and a portion of the subscapularis tendon remain intact Here again we have recession of the tuberosities, so that the upper end of humerus appears like a smooth sphere. (*Right*) Right shoulder There is again complete destruction of the cuff in the supraspinatus and infraspinatus and part of the subscapularis areas. Only a portion of the teres minor and the subscapularis tendons remain intact. Complete recession of the tuberosities has occurred with eburnation of the exposed bone.

contrary this individual was not aware of any disorder in either shoulder and exhibited good movements in all directions Hence, it becomes obvious that such large defects as noted in this series of cases do not preclude good function

Figure 131 shows both shoulders of a female 63 years of age Again these specimens reveal large extensive tears in the musculotendinous cuff, only a small portion of the subscapularis tendons and the teres minor tendons remain intact Both humeral heads exhibit complete atrophy of the tuberosities and obliteration of the intertubercular sulcus In both instances the degenerated biceps tendon lay on a fascial sling made by the remaining intact portion of the subscapularis tendon fibers Degenerative changes in the articular cartilage of the humeral heads are not severe The subacromial bursa in each instance was large and its walls hyperplastic. In each case, the roof of the bursa was adherent to the under surface of the acromion.

Biceps Tendon

After the fourth decade the biceps tendons manifested degenerative changes which increased in gradient in each successive decade The lesions comprised thickening widening and fraying Lesions of this nature, however did not preclude good painless function of the shoulder joint In Figure 132 the biceps tendon exhibited profound degenerative changes, yet the individual who provided the specimen possessed a normal shoulder from a functional viewpoint As previously stated the severity observed in biceps tendons paralleled those in the musculotendinous cuff (Fig 132) Study of the structures forming the exit of the biceps tendon from the joint cavity

FIG 132 J F male white age 59 Left shoulder Note the advanced degenerative changes in the synovialis and fibers of the musculotendinous cuff and the marked shredding, tearing thickening and widening of the biceps tendon. Observe also that on either side of the exit of the biceps tendon the cuff fibers have torn away from their insertion into the posterior and anterior margins of the intertubercular sulcus so that at no point is the tendon constricted.

revealed that there was tearing away of the cuff and the capsular fibers from the anterior and the posterior walls of the intertubercular sulcus so that the tunnel which the biceps tendon traversed was widened Such an arrangement afforded ample room for the tendon and permitted free excursion of the head of the humerus on the tendon In other instances in which the intertubercular sulcus was obliterated by atrophy of the tuberosities the tendon lay in a fascial sling made by the upper border of the tendon of *the subscapularis muscle Here* again, the biceps tendon exhibited no evidence of constriction by the surrounding tissues (Fig 129 *right*)

Figure 133 depicts pecimens obtained from a male aged 73 years At the time of examination he exhibited no impairment of function in either shoulder He readily carried his extremities through all arcs of motion However it was interesting to learn *that 12 to 15 years earlier he had considerable* pain and stiffness first in the right and then in the left shoulder After an indefinite period of time there was gradual restoration of function in both shoulders. From the degree of restriction of motion described one was forced to conclude that a frozen shoulder had existed in each extremity The postmortem pecimens disclosed that the intracapsular portions of both the right and the left biceps tendons were absent, while the proximal ends of the extracapsular portions had attained a bony attachment below the lesser tuberosities Both musculotendinous cuffs exhibited advanced degenerative alterations

DISCUSSION

Critical assessment of the observations recorded above must be tempered by the knowledge that acute traumatic lesions of the shoulder joint as elsewhere in the body, differ from those acquired over a long period of time resulting from slowly progressing degenerative lesions. In the former group there is sudden disruption of the normal mechanics of the joint with no time for nature to make necessary readjustments of structures remaining intact, so that function of the joint will not be severely impaired in the latter group as shown in this study such compensating adjustments are possible and take place when slowly progressing degenerative lesions are the causative factors which produce the alterations in the mechanics of the joint Also it is common knowledge that less extensive tears than those demonstrated in this series but which were produced suddenly by trauma, *may result in marked impairment of shoulder* function One is led to believe therefore that the size of the tear (except in cases of complete avulsion of the cuff) is not the factor which determines the degree

FIG 133 (*Left*) J F male white, age 73 Right shoulder Note that the biceps tendon does not leave the joint through its normal exit. In this instance it has attained a bony attachment to the inferior aspect of the lesser tuberosity The patient who provided these two specimens gave a history that approximately 12 to 15 years prior to his present and last admission to the hospital he had experienced marked stiffness and pain in both shoulders. The symptom complex described was consistent with that of frozen shoulders. (*Right*) Left shoulder This is a matched specimen of the specimen shown at left. Once more the biceps tendon fails to leave the joint cavity but is attached to the lesser tuberosity The intra capsular portion of the biceps tendon in both shoulders was absent. Observe the severe in complete tear involving the supraspinatus and infraspinatus areas of the cuff and also the marked hyperplasia of the torn fibers It is interesting to note that in both illustrations there are only minimal changes in the articular cartilage of each humeral head in spite of the advanced degenerative changes noted in the cuff and the biceps tendon

of impairment of function in the affected shoulder The writer is of the opinion that loss of function in the scapulohumeral joint is in direct proportion to impairment of muscle balance between the rotator muscles which fix and depress the head in the glenoid cavity and the deltoid muscle For example a tear implicating all of the supraspinatus and part of the infraspinatus tendon will produce loss of abduction only when the deltoid muscle is sufficiently strong and powerful to overcome the stabilizing action of the torn cuff and pulls the humerus upward under the acromion when abduction is initiated On the other hand a more extensive tear of the cuff will give rise to no dysfunction if a relatively less powerful deltoid muscle exists and the remaining rotator apparatus still retains sufficient power to fix and depress the head of the humerus in the glenoid cavity when the deltoid muscle contracts In other words so long as the intact portions of the musculotendinous cuff (regardless of the size of the tear) retain sufficient power to balance the action of the deltoid muscle no loss of abduction at the scapulohumeral joint ensues

It becomes obvious that all gradations of dysfunction may exist in different shoulders depending upon the degree of impairment of balance between the rotator apparatus and the deltoid muscle This provides an

explanation for weak abduction or inability to maintain abduction or total loss of abduction in the glenohumeral joint of middle aged individuals mostly laborers, who possess strong powerful deltoids and at operation exhibit only a small or moderate tear in the cuff In this group advanced degenerative alterations resulting from physiologic wear and tear aging and occupational traumata weaken the cuff a small or moderate tear in such a cuff may be sufficient to upset completely the muscle balance which permitted normal unrestricted abduction at the glenohumeral joint Balance having been disturbed varying degrees of impairment of function results The same size tear as mentioned above or even larger may produce no impairment or less impairment in other individuals usually elderly ones who exhibit relatively less powerful deltoid muscles

Considering the frequency of extensive tears in the musculotendinous cuff in this series that were compatible with good function one is further led to assume that nature attempts (and in many instances succeeds) to restore impaired muscle balance following traumatic ruptures of the cuff Therefore it becomes apparent that surgical intervention is justifiable only after sufficient time has elapsed to prove that nature has failed to restore balance

In the light of the above observations referable to the biceps tendon it is obvious that painless normal movements may be present in shoulder joints with marked degenerative lesions in the biceps tendon and surrounding structures provided that the tendon is given ample room as it passes from an intracapsular to an extracapsular position or if the tendon attains a bony anchorage to the shaft of the humerus thereby obliterating the tendon tendon sheath gliding mechanism.

Summary and Conclusions

1 Degenerative lesions of the articular surface of the head of the humerus are never severe, even in the late decades of life and never equal those observed in the articular cartilage of the glenoid fossa

2 Extensive, incomplete tears on the synovial side of the musculotendinous cuff are frequently encountered in shoulders with normal function and do not give rise to the painful arc or supraspinatus syndrome in all instances. In this study there were observed 20.8 per cent incomplete subscapular tears and 37.3 incomplete supraspinatus and infraspinatus tears giving rise to no symptoms

3 Loss of abduction or dysfunction of the scapulohumeral joint does not always occur when large complete tears of the musculotendinous cuff exist. Good function is compatible with massive avulsion of the cuff provided that balance between the deltoid muscle and the remaining intact portion of the rotator cuff is not severely impaired. In this series the incidence of complete tears was 9.3 per cent.

4 From the observations recorded in this investigation it is obvious that nature attempts to restore balance after rupture of the cuff

5 Surgical intervention is only justifiable after sufficient time has elapsed and nature has failed to restore balance

6 Advanced degenerative lesions of the biceps tendon are compatible with good function provided that its tunnel of exit from the joint cavity is widened or the tendon attains a bony attachment to the shaft of the humerus

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explanation for weak abduction or inability to maintain abduction or total loss of abduction in the glenohumeral joint of middle aged individuals, mostly laborers, who possess strong powerful deltoids and at operation exhibit only a small or moderate tear in the cuff In this group advanced degenerative alterations resulting from physiologic wear and tear aging and occupational traumata weaken the cuff a small or moderate tear in such a cuff may be sufficient to upset completely the muscle balance which permitted normal unrestricted abduction at the glenohumeral joint Balance having been disturbed varying degrees of impairment of function results The same size tear as mentioned above or even larger may produce no impairment or less impairment in other individuals usually elderly ones who exhibit relatively less powerful deltoid muscles

Considering the frequency of extensive tears in the musculotendinous cuff in this series that were compatible with good function one is further led to assume that nature attempts (and in many instances succeeds) to restore impaired muscle balance following traumatic ruptures of the cuff There fore it becomes apparent that surgical intervention is justifiable only after sufficient time has elapsed to prove that nature has failed to restore balance

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3 Loss of abduction or dysfunction of the scapulohumeral joint does not always occur when large complete tears of the musculotendinous cuff exist Good function is compatible with massive avulsion of the cuff provided that balance between the deltoid muscle and the remaining intact portion of the rotator cuff is not severely impaired In this series the incidence of complete tears was 9.3 per cent

4 From the observations recorded in this investigation it is obvious that nature attempts to restore balance after rupture of the cuff

5 Surgical intervention is only justifiable after sufficient time has elapsed and nature has failed to restore balance

6 Advanced degenerative lesions of the biceps tendon are compatible with good function provided that its tunnel of exit from the joint cavity is widened or the tendon attains a bony attachment to the shaft of the humerus.

tendinitis, varying degrees of subacromial bursitis, and lesions of the greater tuberosity, such as sharp or rounded exostoses, associated with or without involvement of the cuff The all inclusive syndrome' is justifiable because the pathogenesis of many of these lesions is closely related Moreover, the clinical pictures are similar in many respects Finally, the treatment employed, with few exceptions, is essentially the same

Incomplete and Complete Tears

Clinically tears of the musculotendinous cuff are divided into two categories (1) partial or incomplete tears and (2) complete tears

Partial or incomplete tears are lesions which may involve the synovial or bursal surface of the cuff or tendon fibers within the substance of the musculotendinous cuff Such lesions however never establish a direction communication between the joint cavity and the subacromial bursa. In other words the continuity of the entire thickness of the cuff is never totally interrupted

Complete tears involve the full thickness of the cuff and establish a direct communication between the joint cavity and the subacromial bursa They vary in size from barely perceptible lesions to avulsions of the entire cuff

Clinically the areas of the cuff involved in their order of frequency are supraspinatus area supraspinatus and infraspinatus areas supraspinatus infraspinatus and teres minor areas and supraspinatus, infraspinatus teres minor and subscapularis areas (complete avulsion of the cuff) Tears of the infraspinatus or of teres minor areas singly are encountered rarely if ever However, one does occasionally find a lesion involving only the subscapularis area

These observations differ from those recorded in the study on the synovial side of the cuff In this investigation lesions in the subscapularis area were demonstrable in 41 per cent of the specimens, and supraspinatus lesions in 24 per cent However, tears which involved the entire thickness of the cuff were more frequent in the supraspinatus area It is apparent therefore that lesions in the subscapularis region of the cuff are less likely to give rise to symptoms than those in the supraspinatus area

The frequency of the lesions observed in the supraspinatus region of the cuff is dependent upon several factors

1 **Senescence** It was noted in the investigation on the musculotendinous cuff that degenerative alterations are grossly demonstrable after the fourth decennium and show an increase in gradient in each subsequent decade Therefore, senescence plays a major role in the development of these lesions

Clinically, complete and incomplete tears occur after the fourth decade of life therefore it is reasonable to assume that these lesions are superimposed upon a degenerated and weakened structure The highest incidence is found in the sixth age period Occasionally, they occur in earlier age groups However, in such instances there is usually a history of violent injury often resulting in fracture or dislocation of the humeral head

2. **Attrition.** As pointed out by many observers, the supraspinatus area of the cuff is subjected constantly to frictional trauma as it passes under the acromion and the coraco-acromial ligament when the arm is elevated and abducted and again when the arm is lowered Continued friction is responsible in part for degenerative alterations in the tendon fibers and initiates a chronic inflammatory process in the floor of the subacromial bursa. Synovial villi tabs and proliferative folds develop in the bursa which impinge against the acromion and the edge of the coraco-acromial ligament as the humeral head passes back and forth under these structures

3 **Mechanical and Anatomic Factors.** As previously noted the supraspinatus area both on the synovial and the bursal sides of

4

Ruptures of the Musculotendinous Cuff

INTRODUCTION

Since the masterful and comprehensive study of Codman many excellent publications have appeared in the literature on lesions of the rotator cuff Notable contributors on this topic have been Bosworth Lawrence Jones Outland and Shepherd Inman Saunders and Abbott McLaughlin Wilson Lippmann and Stevens Although one may not be in complete agreement with concepts postulated by these observers they have contributed much valuable information and have provided a keen stimulus for other workers to investigate further this complex region of the shoulder joint

This revived interest in the subacromial region has culminated in the crystallization of certain clinical entities such as complete and incomplete ruptures of the supraspinatus tendon massive and complete avulsion of the rotator cuff calcareous tendinitis subacromial bursitis bicipital tenosynovitis and frozen shoulder Because of the intrinsic anatomy of this region the aforementioned clinical entities are closely interrelated which has caused considerable confusion in differentiating these lesions In fact in many instances a diagnosis can be made only upon visualization of the area Even then, if one is unfamiliar with the detailed anatomy of the region one may easily misinterpret the existing pathologic disorder

In general there is agreement that degenerative alterations of the musculotendinous cuff are responsible for many lesions in the subacromial region This is particularly true of ruptures of the cuff calcareous tendinitis and frozen shoulder As noted (see Chap 2, on Normal Anatomy and Functional Mechanism of the Shoulder Joint and Congenital Abnormalities) the shoulder joint is mechanically inadequate to meet the requirements of a prehensile extremity because of anatomic and phylogenetic factors. During normal joint function the musculotendinous cuff and the biceps tendon are subjected constantly to harmful stresses and strain whose cumulative effect is responsible for early and progressive degenerative lesions in these structures For the same reasons these structures are vulnerable to repeated traumata. In addition to these causative factors senescence is also responsible to a marked degree for degenerative alterations in the cuff

RUPTURES (TEARS) OF THE MUSCULOTENDINOUS CUFF

The term supraspinatus syndrome coined by Bosworth embodies a group of lesions which directly or indirectly involves the supraspinatous region of the musculotendinous cuff It includes complete tears of the tendon incomplete tears calcareous

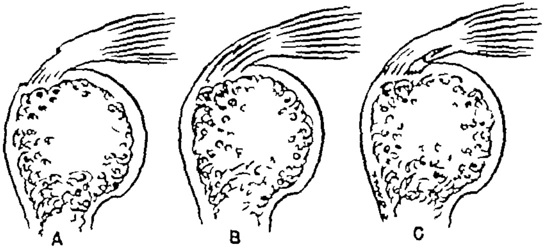

FIG 135 Types of incomplete tears (A) on the bursal side of the cuff, (B) within the substance of the cuff (these lesions are believed by some workers to be the forerunners of calcareous tendinitis) and (C) on the synovial side of the cuff, close to the insertion of the cuff into the head of the humerus

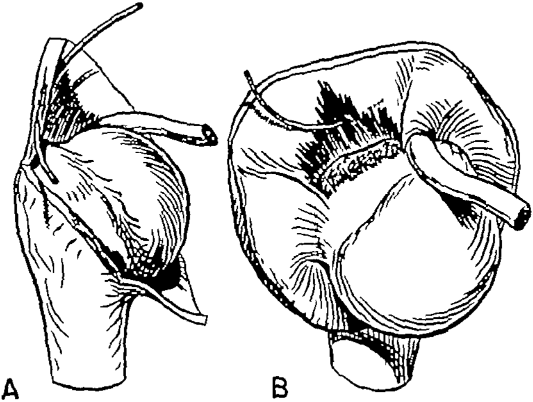

FIG 136 Schematic drawing of actual specimen, showing a large tear on the inner side of the cuff, the fibers have receded from the articular margin and disclose advanced fraying and shredding. The probe is inserted in a longitudinal split in the tendon fibers of the cuff, causing the cuff to laminate into two layers.

Mechanism Responsible for Primary Tears of the Cuff

Direct injuries to the point of the shoulder fail to produce tears of the cuff This region is protected adequately by the overhanging acromion which receives all impacts directed to this region of the shoulder joint. Tears of the cuff partial or complete, are caused by indirect forces which subject the musculotendinous cuff particularly in

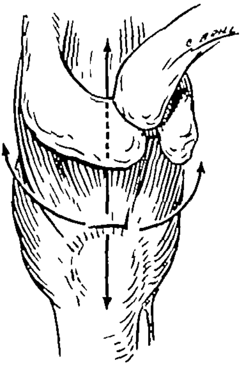

FIG 134 According to Jones rupture of the cuff usually occurs in the supraspinatus tendon which is the weakest portion of the cuff Divergent forces produced by the rotator muscles cause extension of the tear and prevent healing

the cuff exhibited more pronounced degenerative changes than other regions Jones is of the opinion that this *impairment of the cuff* associated with advancing age is accentuated in intensity by divergent forces which act upon the point where the cuff enters the greater tuberosity Slight trauma is now capable of producing a cuff tear in the area of greatest impairment generally located in the supraspinatous tendon just proximal to its line of insertion into the facet of the greater tuberosity Such a defect is subjected to forces pulling in opposite directions, thereby preventing healing and favoring extension of the tear (Fig 134)

The musculotendinous cuff is anatomically and mechanically inadequate to meet the requirements of a prehensile extremity and present-day endeavors which demand the arm to function in an abducted or elevated position In the discussion on motions of the shoulder joint it was noted that the prime function of the cuff is to provide a *fulcrum for the head of the humerus in the* glenoid cavity This is accomplished by the combined and simultaneous action of the rotator muscles which fix and at the same time depress the humeral head in the glenoid cavity

In addition the supraspinatus muscle is an active abductor of the arm acting as the short arm of a long lever In spite of the functional demands made on the supraspinatus *muscle, it is the smallest and least* powerful of the four component muscles of the cuff

In the light of the afore mentioned observations one is forced to conclude that the supraspinatus region of the cuff is subjected *to great attritional forces resulting in early* and severe degenerative alterations in this area This concept is substantiated by clinical observations and by studies made on cadavers.

4 **Occupations.** Occupations are recognized predisposing factors in inflicting undue wear and tear on the rotator cuff Lesions are encountered most frequently in individuals engaged in laborious occupations and athletic endeavors Men are affected more frequently than women in a ratio of approximately 10 to 1 The right shoulder is more frequently involved than the left

HISTORY OF INJURY

In all instances a history of injury can be elicited the most frequent being a fall on the outstretched arm Sometimes the injury is of as mild a nature as picking up some object or elevating the arm suddenly This is particularly true in the older decades (past the sixth) However severe trauma is an essential prerequisite to initiate the syndrome in individuals in the first three decades of life Fractures or dislocations of the humeral head are more likely to occur in this age group than a tear of the musculotendinous cuff

lesions are not encountered frequently Transverse tearing of the fibers occurs in the cuff slightly proximal to its line of insertion into the tuberosity When retraction of the torn fibers occurs, it is very slight because the edges of the defect are continuous with the adjacent intact cuff Codman was of the opinion that most primary tears were transverse in nature, that the edges of the defect were anchored by the adjoining conjoined tendon and that retraction of the muscle made the rent triangular Also he believed that the width of the tear was the width of the base and that restoration would be attained if the apex of the triangle were sutured to the middle of the base McLaughlin, however, is not in agreement with this concept and has offered an entirely different mechanism for the production of triangular and crescentic lesions which are advanced stages of primary transverse tears

It was of some significance to note that pure transverse complete tears were not disclosed in the investigation on the musculotendinous cuff in cadaver or autopsy specimens. As a rule small tears were irregular, circular defects in the cuff, some of which exhibited a longitudinal extension of varying length starting from the anterior margin of the defect. Larger tears were either triangular or crescentic Therefore it is reasonable to assume that a transverse tear demonstrable at operation is produced by injury (usually in the form of excessive strain) superimposed upon a weakened and degenerated cuff

2 **Pure Vertical Rents or Longitudinal Slits Paralleling the Direction of the Cuff Fibers.** Longitudinal tears vary considerably in size They occur invariably in young individuals who have sustained violent injuries to the shoulder joint Not infrequently such lesions are associated with fractures or dislocations of the humeral head In general the rent runs parallel with the joint cavity through the fibers of the coracohumeral ligament which occupies the interval between the supraspinatus and the subscapularis muscles and which bridges the intertubercular sulcus

One case disclosed a tear extending from the greater tuberosity to the base of the coracoid process As pointed out by McLaughlin, the lesion may continue into the substance of the upper end of the humerus as far as the surgical neck In these instances the greater tuberosity is fractured at its base and pulled upward and backward by the external rotators while the humeral head is displaced downward and forward by the pull of the subscapularis muscle It is obvious that the opposing forces of the external rotators and the internal rotator (the subscapularis muscle) tend to separate the edges of a longitudinal rent thereby preventing healing and favoring extension of the tear

As was noted in the discussion on transverse tears, complete longitudinal lesions were not observed in cadaver or autopsy specimens Although vertical separation and shredding of the cuff fibers were common observations no instance of a complete rent confined to the region of the coracohumeral ligament was encountered This observation leads one to conclude that such lesions invariably result from violent injury, inflicted upon the strong and healthy musculotendinous cuffs of young individuals capable of resisting transverse tears

3 **Tears with Retraction.** According to McLaughlin, excessive strains beyond the capacity of a weakened degenerated cuff produce primary transverse tears

Repeated and continued strains upon the lesions are responsible for longitudinal splitting of the cuff, starting at one end of the transverse tear and extending proximally parallel with the joint cavity The longitudinal split usually takes place at the anterior end of the transverse tear Further traumas minor or severe, tend to increase the extent of the lesion both in the transverse and the longitudinal axes of the cuff fibers Also, the longitudinal arm of the lesion is acted upon by the divergent forces of the subscapularis muscle, which pulls the

the supraspinatus region, to great strain beyond its functional capacity Under normal conditions, strains of this nature would not evoke a tear of the cuff However, degenerated cuffs are unable to meet such strains and tears of varying degrees result The sizes and the locations of the tears depend upon the severity of degenerative alterations in the cuff and the amount of strain acting upon it. The usual history obtained is one of falling on the outstretched arm It is reasonable to assume that the severity of the strain thrown on the supraspinatus area by sudden elevation of the arm is sufficient in itself to cause a tear of the cuff before the individual strikes the ground

Incomplete Tears in the Supraspinatus Region of the Cuff

These lesions exhibit a diversity of pathologic alterations. Nevertheless they possess a common denominator in that the entire thickness of the cuff is not affected Essentially they can be divided into four types (1) tears on the synovial side of the cuff (2) tears within the substance of the cuff without the involvement of either synovial or bursal surfaces (3) tears on the bursal side of the cuff and (4) tears running parallel with the cuff fibers (Fig 135)

1 **Tears on the Synovial Side of the Cuff (Rim Rents)** Such lesions involve the deep tendon fibers which together with the synovialis are torn from their bony insertion (Fig 136) Retraction of the fibers gives rise to a mobile tab of tissue which as emphasized by McLaughlin and Bosworth may produce symptoms of internal derangement of the shoulder joint comparable with internal derangement of the knee associated with lesions of the menisci

In acute and subacute lesions an active reparative process may be initiated which produces pronounced thickening of the torn fibers at the base of the tear Such a thickened and hypertrophied portion of the cuff is responsible for the soft crepitus and jog often demonstrable in affected shoulder joints. The soft crepitus and jog are discernible when the thickened portion of the cuff impinges upon and then passes under the acromion or the falciform edge of the coraco-acromial ligament Chronic lesions also may disclose some thickening of the torn fibers and base of the tear resulting from advanced fibrosis caused by the increased friction in this region Occasionally there may be considerable thinning in the impaired portion of the cuff

2. **Tears Within the Substance of the Cuff Without Involvement of the Synovial or Bursal Surfaces.** Tears may occur in the central fibers, causing the cuff to laminate into two or more layers (Figs 135 and 136)

3 **Tears on the Bursal Side of the Cuff** Such lesions reveal tearing of the superficial fibers just proximal to their point of insertion into the facet of the greater tuberosity (Fig 135A) Fresh lesions always demonstrate the distal remnants of the cuff fibers still attached to the tuberosity The floor of the subacromial bursa is involved in all these lesions The constant irritation produced by the defect in the cuff frequently causes pronounced thickening of the bursal floor Numerous villi and thick synovial folds covering the bursal floor are frequent findings It is obvious that such lesions hinder smooth joint motion and give rise to symptoms similar to those found in tears on the synovial side of the cuff

4 **Tears Running Parallel with the Cuff Fibers.** These lesions are the least frequently encountered Here again the overlying bursa always is affected and discloses changes similar to those noted above

Complete Tears in the Supraspinatus Region of the Cuff

McLaughlin has given us the most comprehensive classification of these lesions. He divides them into four groups pure transverse ruptures pure vertical rents tears with retraction and massive avulsion of the cuff

1 **Pure Transverse Ruptures.** These

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2. **Pure Vertical Rents or Longitudinal Slits Paralleling the Direction of the Cuff Fibers** Longitudinal tears vary considerably in size They occur invariably in young individuals who have sustained violent injuries to the shoulder joint Not infrequently such lesions are associated with fractures or dislocations of the humeral head In general the rent runs parallel with the joint cavity through the fibers of the coracohumeral ligament which occupies the interval between the supraspinatus and the subscapularis muscles and which bridges the intertubercular sulcus

One case disclosed a tear extending from the greater tuberosity to the base of the coracoid process As pointed out by McLaughlin, the lesion may continue into the substance of the upper end of the humerus as far as the surgical neck In these instances the greater tuberosity is fractured at its base and pulled upward and backward by the external rotators while the humeral head is displaced downward and forward by the pull of the subscapularis muscle It is obvious that the opposing forces of the external rotators and the internal rotator (the subscapularis muscle) tend to separate the edges of a longitudinal rent, thereby preventing healing and favoring extension of the tear

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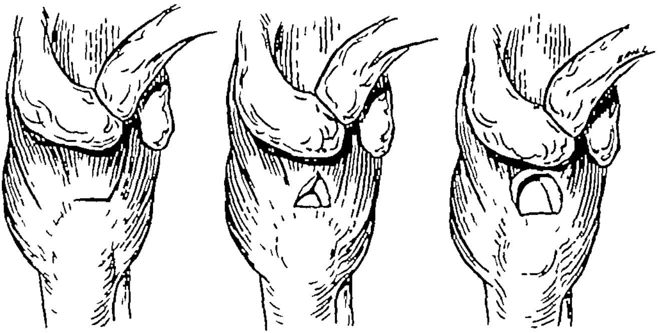


FIG 137 McLaughlin's concept of the formation of cuff defects. (A) First a transverse tear or rupture of varying size occurs as the result of trauma inflicted on a degenerated cuff (B) Repeated traumata cause extension of the tear both in the transverse and longitudinal axis. (C) Divergent forces act on the longitudinal arm of the tear the subscapularis pulls the anterior edge of the tear forward and the external rotators pull the posterior edge backward producing a triangular or crescentic effect.

anterior margin of the tear forward and the external rotators which pull the posterior margin backward thereby producing the typical triangular or crescentic defect disclosed at operation (Fig 137)

It is apparent from the afore mentioned observations that a triangular or crescentic lesion is a combination of a transverse and longitudinal tear In old lesions a smooth hypertrophied margin is discernible around the entire defect on the synovial side of the cuff This is nature's frustrated attempt to limit the defect and is really a reparative process in the torn synovialis proximal to the defect in the cuff fibers Codman designated this thickened synovial margin the "falciform ligament" As a result of this attempt at repair the retracted edges of the gap are smooth A distinct transverse or longitudinal rent is no longer demonstrable so that one may readily misinterpret the lesion as a transverse tear superimposed by retraction of the muscle (the supraspinatus muscle) As previously stated this concept differs from that of Codman who believed the above defects to be the result of retraction of the supraspinatus muscle following a transverse tear in its tendinous insertion

4 **Massive Avulsion of the Cuff** Such lesions comprise avulsion of a large segment of the cuff (usually all the external rotator tendons are involved) with retraction. The longitudinal tear takes place in the interval between the supraspinatus and the subscapularis muscles through the fibers of the coracohumeral ligament Occasionally the lesion includes part of the subscapularis tendon In these instances the longitudinal tear extends medially through the subscapularis muscle Not infrequently the torn and retracted cuff hangs like a curtain between the head of the humerus and the glenoid cavity McLaughlin applied the term complete avulsion to those cases in which the entire musculotendinous cuff (all four rotator tendons) is avulsed and retracted from the humerus.

Lesions as described above occur in the aged as a rule although occasionally they are noted in younger individuals who sus-

tained violent trauma They are often con comitant lesions of anterior dislocations and often responsible for chronic subluxation of the shoulder

Clinical Features

1 Complete Tear in the Supraspinatus Region of the Cuff Codman's classic de scription of the clinical features of a rup ture of the supraspinatus tendon is so com plete and comprehensive that no one as yet has been able to add anything new One is forced to draw heavily from this rich source of information when considering the diag nostic features of this clinical entity

At this point for the sake of facilitating comprehension of the clinical picture that is to follow some repetition referable to the anatomy of the musculotendinous cuff is justifiable All four rotator tendons are welded together with the fibrous capsule into one musculotendinous sheath which inserts into the upper half of the anatomic neck of the humerus The fibers of the four tendons interlace so intimately with one another and with the fibers of the capsule that it is impossible to separate the com ponents of any one tendon at its point of insertion even with sharp dissection

Since the supraspinatus region of the cuff is subjected to the greatest amount of strain generally all complete tears involve this area. At first the rupture may involve only the supraspinatus region of the cuff, then as the result of further strain it may extend laterally to involve the infraspinatus and the teres minor regions Medial extension of the tear will involve the subscapularis area On the other hand massive or com plete avulsion of the cuff may occur at the time of the initial trauma It becomes obvi ous that the clinical features are dependent upon time the severity of the lesion and the extent of secondary pathologic altera tions that ensue in the subacromial bursa the humeral head the tuberosities and the biceps tendon

The pertinent clinical features of com plete tears are (1) age, (2) occupation (3) a history of injury, (4) pain, (5) im paired function and (6) the local clinical features

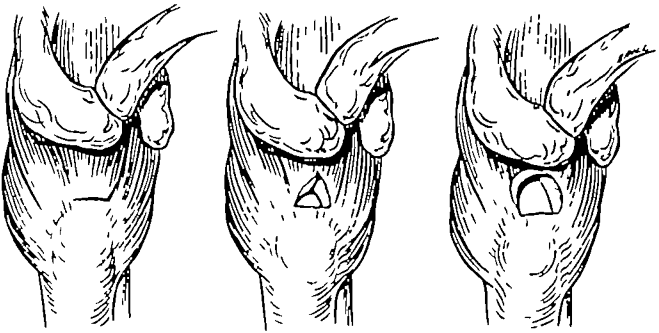
Age Such lesions usually occur past mid dle age, during which period there is in disputable evidence of attritional changes in the musculotendinous cuff When com plete tears occur in younger individuals there is always a history of violent trauma

Occupation In general, the lesions occur in individuals who perform strenuous work These individuals not only inflict constantly minor trauma to their cuffs, thereby favor ing progressive degenerative disorders, but also by the very nature of their work are vulnerable to trauma which may precipi tate a complete tear

History of Injury A history of injury is invariably available Falling on the out stretched arm is the most common form of injury Next in frequency is one of sudden abduction of the extremity while grasping a heavy object" (Codman) Occasionally it is difficult to correlate the clinical picture with the mechanism of production which may appear minor and insignificant How ever, if one visualizes the extensive degen erative abnormalities present in the cuff of the person affected, it becomes obvious that minor trauma is sufficient to produce ex tensive avulsion of such a damaged struc ture The writer has seen in elderly indi viduals two cases of massive avulsion of the cuff resulting from shock therapy

Pain Sudden sharp pain at the time of the injury is a constant and characteristic feature Although the pain is localized at the tip of the shoulder, it is also referred to the insertion of the deltoid muscle Often the patient will volunteer that a sensation of something snapping' or 'tearing was felt in the shoulder Within a few hours the acute pain subsides only to recur with greater intensity in the next 6 or 12 hours For the next several days (4 to 7 days) there is an increase in the intensity of the pain which then gradually diminishes

Hemorrhage continues to distend these structures for several days thereby produc



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Lesions as described above occur in the aged as a rule although occasionally they are noted in younger individuals who sus-

role in abduction of the arm They establish a fulcrum for the humeral head in the glenoid cavity by holding the head firmly against the glenoid and, at the same time, depressing it They guide or direct the pull of the deltoid muscle In addition, the supraspinatus is also an abductor of the arm but does not initiate the abduction It acts simultaneously with the deltoid throughout the entire arc of abduction Such a mechanism is essential in order to attain full and powerful abduction and elevation of the arm If there exists a massive tear of the cuff and if the rotator apparatus which remains intact is not sufficient to stabilize the humeral head, the humeral head is unable to obtain a fulcrum on the glenoid cavity, being displaced under the acromion by powerful contractions by the deltoid in a vertical direction No scapulohumeral motion is now possible, although the scapula can rotate on the thorax from 60° to 70° Cuffs with lesser tears may provide a fulcrum for the humerus sufficient to permit weak abduction in the scapulohumeral joint The fulcrum, however, is not sufficiently stable to allow abducting the arm against resistance or to maintain abduction Small tears which do not severely lessen the efficiency of the cuff are compatible with smooth powerful abduction particularly if the impairment does not give rise to symptoms of internal joint derangement.

It was noted in the investigation dealing with degenerative lesions (p 105) that the size of the cuff tear (except in cases of complete avulsion of the cuff) is not the factor which determines the extent of dysfunction in the involved extremity Loss of function (primarily that of controlled powerful elevation of the arm) of the scapulohumeral joint is in direct proportion to the impairment of muscle balance between the rotator muscles which fix and depress the head of the humerus in the glenoid fossa and the deltoid muscle This is also true of the power to abduct the arm against resistance and to maintain abduction

This affords an explanation for the marked impairment of function in individuals with strong powerful deltoid muscles who suffer only small or moderate tears of the cuff, and for good function in elderly individuals with extensive or massive avulsions of the cuff who possess small and relatively less powerful deltoid muscles In the first group, which mostly includes laborers past the fourth decade, the deltoid muscle is unusually well developed, strong and powerful, while the rotator apparatus may show extensive degenerative lesions resulting from physiologic wear and tear and repeated occupational traumata. A small or moderate tear (for example, one involving the supraspinatus and a portion of the infraspinatus muscle) in this group may disturb sufficiently the balance between the deltoid and the rotator muscles so that pronounced impairment of function results as total inability to abduct the arm or weak abduction and inability to maintain abduction

On the other hand, extensive tears of the cuff in individuals with less powerful deltoid muscles may give rise to little or no apparent dysfunction, provided that power in the remaining intact rotator cuff is sufficient to stabilize the head of the humerus by balancing the contraction of the deltoid muscle

Faulty scapulohumeral rhythm is a constant feature of complete tears of the cuff It also may be exhibited with impairment of function resulting from loss of balance between the deltoid and the rotator muscles, by incomplete tears and calcareous tendinitis, if pain and muscle spasm exist Normally, during elevation and abduction motion is smooth, simultaneous and continuous in both the scapulothoracic and the scapulohumeral joints There is a constant relationship of scapular to humeral motion, the ratio being two of humeral motion to one of scapular motion (Inman, Saunders and Abbott) In persons with cuff tears which impair function this relationship is altered As the arm is raised to the hori

ing increasing 'tension pain ' With cessa tion of bleeding the hemorrhage is absorbed slowly, and the pain subsides During this acute painful period there is marked protective muscle spasm which precludes ade quate examination of the part In the latter stage the pain is constant but less intense It is projected to the insertion of the deltoid muscle and at times to the anterior aspect of the arm It is accentuated by activity and interferes with the individual s sleep

Impaired function may result from abnormal mechanical factors or pain which produces muscle spasm on attempts at motion In the acute stages pain and muscle spasm may be so pronounced that the sever ity of the lesion cannot be ascertained by physical examination This may be true in extensive lesions of the cuff or in such trivial ones as tears of a few of its fibers in the supraspinatus and the infraspinatus regions

Severe pain occurs in instances of minor cuff damage only when the torn portion of the cuff passes the acromion or the coracohumeral ligament during abduction of the arm Immediate relief takes place after the tender tissues have passed beneath these structures This painful arc of movement is between 80 and 110 or 120° As the arm is lowered to the side pain is again felt at 120° and disappears at 80 If the rupture is not too extensive free painless abduc tion is possible if the pain factor is elimi nated This can be accomplished readily by infiltration of the torn cuff with procaine (5 cc of a 1 per cent solution)

Also depression of the humeral head manually by the examiner as the arm is abducted will prevent impingement of the impaired cuff against the coraco-acromial arch hence no pain is felt Free painless motion without restriction in these instances can be demonstrated by having the patient stoop to a horizontal position with the knees extended and the arms hanging loosely toward the floor In this position all muscles around the shoulder girdle, including the deltoid are relaxed. Thus the patient requires little effort to swing the arm into a position of complete elevation If the examiner supports the weight of the arm as the patient regains the upright position complete elevation can be maintained by the patient, even if the supraspinatus is torn.

The degree to which normal function is impaired depends upon the extent of the cuff tear and the associated secondary changes in the adjacent structures. Codman expressed the belief that all complete supra spinatus tears should be repaired, and the repair should be done immediately The writer, together with other observers, is not in agreement with this concept Complete tears of the cuff within certain limits are compatible with normal and painless shoul der motion In the investigation on shoulder joints, obtained postmortem from individ uals who were not aware of any impairment of function prior to their death, it was noted that nine shoulder joints disclosed complete tears of the cuff ranging in size from 1 cm. to massive avulsion

Moreover the writer has explored shoul der joints which exhibited clinically the cardinal features of a bicipital tenosynovitis. In addition to this lesion complete tears of the supraspinatus region of the musculotendinous cuff were demonstrable The tears ranged in sizes from 1 to 4 cm For investi gative reasons the cuff tears were not repaired The biceps tendon was transplanted to the coracoid process In all these cases there was complete restoration of free pain less joint motion

As previously noted in the acute stages it is impossible to make a correct diagnosis of complete rupture of the cuff because of the associated pain and muscle spasm. In the later stages if the tear is extensive enough to prevent firm fixation of the humeral head in the glenoid cavity impaired function is discernible This is mani fest by an inability to abduct or maintain abduction and faulty scapulohumeral rhythm

Through the musculotendinous cuff the rotator muscles normally play an important

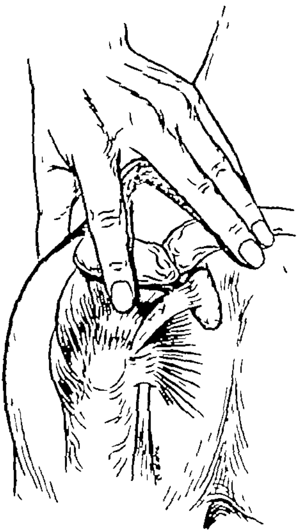

FIG 140 The tip of the forefinger in position to elicit point of maximum tenderness in cases with rupture of the supraspinatus region of the cuff The finger *drops into the sulcus pressure* over this region causes severe pain The eminence may be palpated just external to the sulcus.

FIG 141 *Roentgenograph of patient* with large tear of the cuff Note the prominent irregular tip of the greater tuberosity and slight *condensation of* cortical bone just medial to the eminence.

of the tuberosity Tenderness over the mid point of the outer surface of the humeral head is indicative of involvement of the teres minor region of the cuff Also tenderness can always be elicited at the insertion *of the deltoid In fact many of these* patients will volunteer to say that there is pain in this region but fail to mention that there is a tender area at the point of the shoulder In the acute stage there is marked sensitivity at the site of the tear Sensitivity diminishes with time and in long standing cases it is not a very significant sign (Figs 138-141)

Jog and Soft Crepitus A characteristic catch or jog and soft crepitus can be felt by the patient and the examiner as the arm is *abducted beyond the horizontal position* They are produced when the impaired portion of the cuff and the tuberosity (eminence) impinge upon and then pass under the acromion or the coraco-acromial ligament. Both *jog and* crepitus are again palpable when the arm is lowered as the torn and sensitive cuff and the tuberosity pass from under the coraco-acromial arch. Although these signs (together with the afore-mentioned clinical features) *are presumptive* evidence of a complete tear of the cuff they may be demonstrable also in *other lesions* responsible for internal derangement of the shoulder joint.

Atrophy of the Rotator Muscles Atrophy of the pinatii is a constant sequel of this

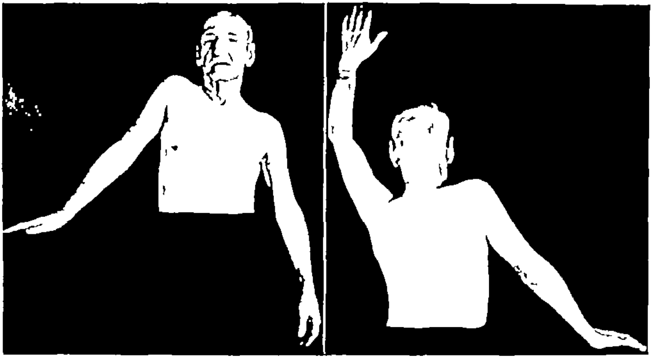

FIG 138 Patient showing maximum range of abduction that was possible with large complete rupture of the cuff, implicating all the supraspinatus and one-third of the infra spinatus regions of the cuff

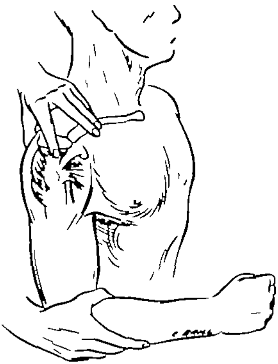

FIG 139 Hands in position for exami nation of shoulder The thumb lies just below the spine of the scapula while the tip of the forefinger is just anterior to the acromion the other three fingers hold the clavicle The entire shoulder girdle now is firmly grasped by the hand and any motion in the glenohumeral joint is readily discernible.

zontal position one notes that all motion takes place in the scapulothoracic joint while the glenohumeral joint is fixed in a position of flexion From the horizontal position elevation of the arm is completed by motion entirely through the gleno-humeral joint When the arm is lowered the relationship between the capula and the humerus is not altered until the horizontal position is reached In other words the arm approaches the horizontal from the position of complete elevation with the glenohumeral joint fixed in the position of extension all motion taking place in the scapulothoracic joint From the horizontal the arm is sud denly dropped to the side this last phase of motion taking place in the glenohumeral joint

LOCAL CLINICAL FEATURES

Tenderness Marked tenderness can in variably be elicited over the tip of the greater tuberosity (superior facet) When the lesion extends into the infraspinatus region point tenderness can be demon-strated slightly below the lateral to the tip

FIG 145 (*Left*) Supraspinatus region of cuff at the point of insertion into the head of the humerus in a male 56 years old, with no shoulder dysfunction. Observe the advanced shredding, tearing fibrillation of the tendon fibers increase in connective tissue formation and the appearance of numerous blood vessels. (X 62)

FIG 146 (*Right*) Cuff disclosing hyalinization of the degenerated fibers and profound increase in connective tissue elements. Case of male 60 years old with no shoulder dysfunction (X 62)

entity The degree of atrophy is dependent upon the severity and the duration of the lesion When the affected shoulder joint is compared with the opposite normal side one will note that the muscles exhibiting most pronounced atrophy are the supraspinatus the infraspinatus, the teres minor and the trapezius muscles. The deltoid muscle may disclose apparent or real hypertrophy From what was noted previously in the discussion on impaired function it is apparent that when the cuff fails to provide an adequate fulcrum, the deltoid undergoes powerful contractions with each attempt to abduct or elevate the extremity Such excessive demands result in hypertrophy of the deltoid muscle.

Radiographic Examination Unless there is involvement of the osseous elements of the humerus radiographic examination reveals no significant observations In the presence of marked muscle spasm in the early stages the humeral head may be found high in the glenoid cavity

Long-standing cases may show some increased localized density in the tip of the greater tuberosity and at times some spurring in this region In such instances definite extoses also may be demonstrable on the tip of the greater tuberosity (Fig 141)

Cases with massive and complete long standing avulsions of the cuff may reveal "recession of the tuberosities and hypertrophic changes on the outer surface of the humeral shaft Anteroposterior lateral and oblique views may be necessary to show the above lesions (Fig 142)

Presence of Fluid Increased amounts of synovial fluid can be demonstrated in most instances of old complete tears It is only demonstrable when the arm is elevated as far as is possible and is palpable in the subacromial bursa beneath the deltoid muscle When the arm is at the side the fluid gravitates to the inferior regions of the capsule Continued distention of the bursa in old cases produces marked thickening of the bursal walls This was a common observa

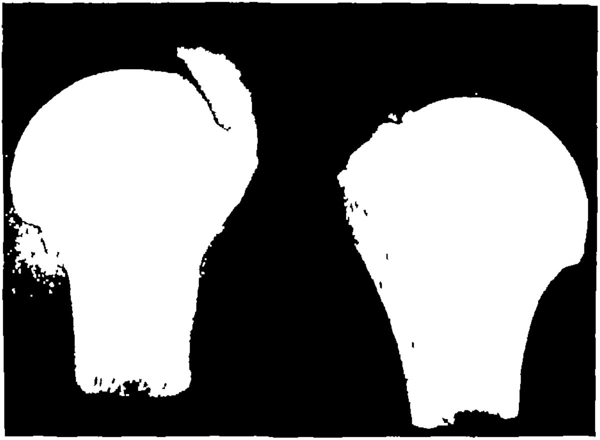

FIG 142 Roentgenograph of the head of the right humerus of a patient with old complete tear of cuff (postmortem specimen) Observe the recession and atrophy of the greater tuberosity and irregularity of the superior and lateral surface of the shaft of the humerus resulting from the formation of bony excrescences.

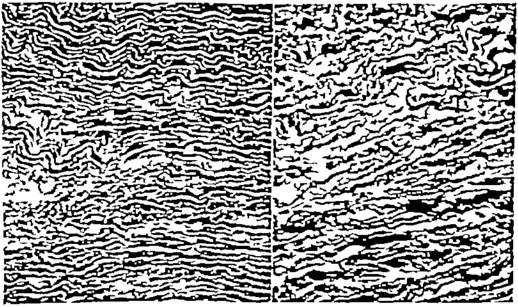

FIG 143 (*Left*) Supraspinatus tendon showing no degenerative alterations of an *individual 30 years old Observe the continuous wavy pattern* of the collagenous fibers and the paucity of cellular elements and blood vessels. (× 75)

FIG 144 (*Right*) Supraspinatus region in an individual 42 years old Note moderate degenerative changes manifested by loss of the wavy pattern of collagenous fibers fibrillation and shredding of fibers note also the increase in cellular elements blood vessels and connective tissue. (× 150)

subside, the *nature of the syndrome* varies with the severity of the lesion

It has been demonstrated conclusively *that not all complete tears* give rise to symptoms, nor do they always impair function Lesions extensive enough to impair function by failure of the rotator apparatus to balance the action of the deltoid muscle are recognized readily because all the previously mentioned cardinal features of this syndrome are usually present

2. **Incomplete Tears in the Supraspinatus Region of the Cuff** The pertinent clinical features of this entity are similar to those of complete *tears of the cuff* As a rule, they are less pronounced, and such local signs as the presence of an eminence and a sulcus may be absent in some instances Inasmuch as there is no communication between the joint cavity and the subacromial bursa, it is impossible for synovial fluid to accumulate under the deltoid muscle Hence *it is not demonstrable*

At times, accurate diagnosis of an incomplete tear of the cuff may be very difficult However there is *one* cardinal feature which distinguishes it from complete tears Good power of abduction and elevation is always present in incomplete tears Poor and weak power of abduction and elevation is a characteristic *feature* of complete tears sufficiently large to cause impaired function. However, even at the risk of criticism for repetition it must be restated that a multitude of entities present clinical pictures comparable with that of incomplete tears of the cuff making visualization of the area imperative in order to arrive at a *correct diagnosis*

TREATMENT

Conservative Treatment of Incomplete Tears

1 **Recent Lesions.** During the acute stage treatment should be entirely palliative directed toward *alleviation* of pain overcoming muscle spasm restoration of motion, prevention of muscular atrophy and prevention of disturbing sequelae Sedatives may have to be administered (especially before retiring and for several days) until the acute pain subsides Infiltration of the supraspinatus region of the cuff with 5 cc. of 1 per cent procaine solution *often* gives dramatic relief from pain relieves muscle spasm and restores motion It may be necessary to repeat the procedure *three* or four times on successive days

Rest of the part is essential, particularly *in severe lesions This is best attained by* placing the arm in a sling However, one should guard against complete immobilization *of the arm*, because serious sequelae may occur At frequent and regular intervals during the day (every 2 or 3 hours) the arm should be removed from the sling and the patient should be encouraged to put the arm through a routine of gravity free pendulum exercises for short periods of time (3 to 5 minutes) Physical therapy in the form of *radiant heat and gentle massage* may be added to the program With cessation of the acute symptoms (after 4 or 5 *days) the sling is discarded, and* wall crawling exercises are started Caution must be taken not to allow the patient to *force* the arm beyond the tolerance of pain and fatigue

Mobility is a very essential part of the program, for one must remember that these lesions occur in individuals past middle life *in whom degenerative* cuff changes are present in varying severity Immobilization together with degenerative alterations in the cuff may *initiate inflammatory processes* which terminate in frozen shoulders

At no stage during the treatment is any type of passive manipulation of the shoulder justifiable Such procedures only inflict *further* damage to the cuff and favor further formation of adhesions

Resumption of normal arm motions must be encouraged as *soon* as the *acute* symptoms subside Progressive use up to the point of tolerance and fatigue is the secret of successful treatment

If such a program is adhered to strictly


FIG 147 (*Left*) Supraspinatus region of cuff in a female 56 years old. Note bone formation within the substance of the cuff The individual was not aware of any shoulder impairment. (× 62)

FIG 148 (*Right*) Portion of a ruptured supraspinatus tendon of a female aged 48 Note the extensive degenerative alterations of the cuff fibers. Although more severe, the nature of the abnormalities is similar to that depicted in Figure 144 (× 62)

FIG 149 Cuff shown in Figure 148 (× 152)

tion in cadaver and autopsy specimens (Fig 130, *left*)

Eminence and Sulcus Tears extensive enough to give rise to impaired function can often be diagnosed by the presence of an *eminence and a sulcus.*" The sulcus is a palpable defect at the site of rupture in the musculotendinous cuff The eminence is the normal prominence of the tuberosity, to which may still be attached some remnants of the insertion of the cuff It is located and can be readily palpated just anterior to the edge of the acromion when the arm is in dorsal flexion The jog and soft crepitus is caused by the passing of the eminence and the sulcus *under the acromion* and the coraco-acromial ligament

In summary one is safe in saying that in the early acute stage when severe pain and muscle spasm obscure the clinical picture it is not possible to make a positive diagnosis of complete tear in the supraspinatus region of the cuff After the acute symptoms

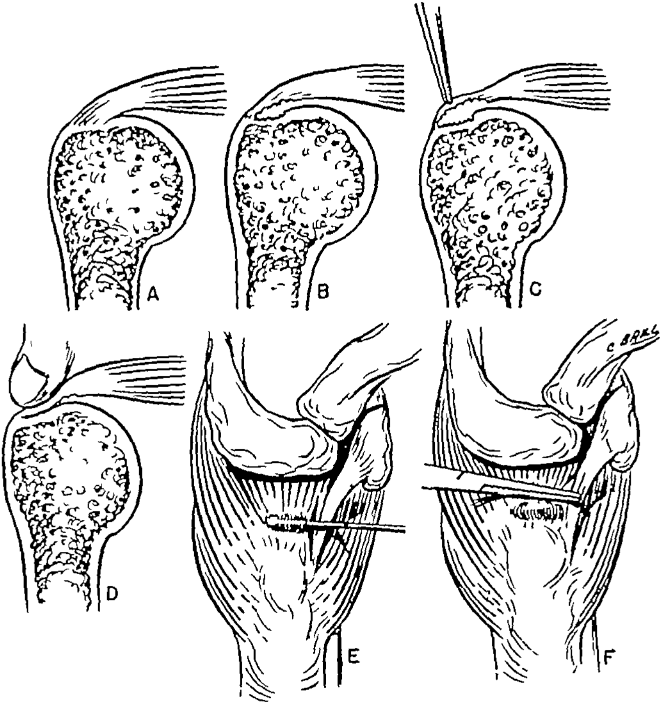

FIG 150 Aids in arriving at a diagnosis of incomplete tears of the cuff (A) Normal insertion of the cuff into the humeral head fibers are firmly attached and cannot be lifted off (B) Rim rent or incomplete tear (C) Outer fibers of cuff in incomplete tears can be lifted from the head of the humerus. (D) Finger can palpate sulcus and irregularities on the humeral head through the thinned cuff (E) Longitudinal split in cuff will permit probe to be inserted into the side of the cuff, also permitting visualization of the inner surface of the cuff (F) Blister is raised when instrument is passed laterally over the cuff (Redrawn with modifications from McLaughlin)

1 Normally upon abduction of the arm in various planes of rotation the musculotendinous cuff passes under the coraco-acromial arch without a wrinkle on its superficial surface. However if a rim rent is present, as the arm is abducted a wrinkle or blister" forms at the site of the lesion as it approaches the falciform edge of the coraco-acromial ligament or edge of the acromion

the great majority of the patients will attain complete, painless restoration of function within from three to six weeks. Operative treatment is warranted if satisfactory improvement is not attained but it is never justified before ten to twelve weeks

2 **Old Lesions.** Old incomplete tears deserve a fair trial at conservative measures before surgical intervention is contemplated Many cases respond favorably under a carefully planned regimen of treatment It is of prime importance to gain the confidence of the patient in the execution of such a program Objectives to be achieved are restoration of complete motion and alleviation of pain.

Relief from pain is attained by such measures as radiant heat, gentle massage and infiltration of the area of maximum tenderness with 1 per cent procaine Rest is another essential feature of the program Painful arcs of motion should be avoided and restraint from strenuous activity should be insisted upon

Restoration of motion can be achieved by graduated pendulum and wall-crawling exercises performed within the tolerance of pain and fatigue At no time should one resort to manipulative procedures in an attempt to restore full range of motion Formation of more adhesions following manipulation invariably results in greater restriction of motion

With such a program satisfactory results should be attained in from four to six weeks although in some instances several months of intensive therapy may be necessary before satisfactory recovery is obtained Failure to attain improvement is sufficient justification for operative intervention particularly if pain, muscle spasm and restriction of motion are of such severity that joint function is markedly impaired

Conservative Treatment of Complete Tears

During the acute stage treatment is similar to that described for incomplete tears. As previously noted many minor complete tears give no functional impairment after the acute painful symptoms have subsided More severe tears may improve spontaneously without too much residual disability, a matter acceptable to both the patient and the surgeon

These clinical observations make it mandatory that a sufficient interim be allowed between initial injury and decision for surgical intervention. From six to eight weeks is not too long an interval to elapse before operative repair of the lesion is undertaken McLaughlin has recorded that his end result studies of early and late repairs revealed no appreciable differences in functional recovery This concept is not in agreement with Codman Mosely and Bosworth who are of the opinion that the results of early operation are superior to those of late operation The author s end results substantiate McLaughlin s observations.

Other factors should be weighed thoroughly before one decides upon surgical intervention Elderly inactive people with marked functional impairment of the shoulder who tolerate the disability without too much discomfort should not be subjected to surgical procedures On the other hand, active individuals who reveal pronounced weakness in sustaining abduction against resistance or who are unable to sustain abduction after the arm is abducted passively should be offered operative relief

Surgical Treatment

1 **Incomplete Tears.** The sole objective of operative intervention in this type of lesion is to allay abnormal friction between the coraco-acromial arch and the musculotendinous cuff Whereas the continuity of the cuff is not interrupted it is often difficult to identify and localize lesions in the synovial side As previously recorded in many instances the bursal floor appears relatively normal yet extensive fraying tearing and shredding of tendon fibers exist on the joint side of the cuff (Fig 150) McLaughlin described four simple maneuvers which solve this problem

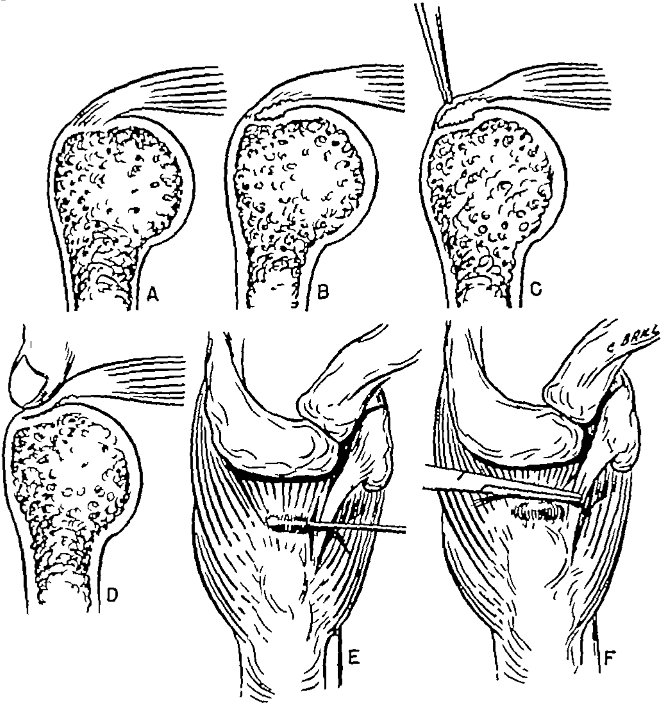

FIG 150 Aids in arriving at a diagnosis of incomplete tears of the cuff (A) Normal insertion of the cuff into the humeral head fibers are firmly attached and cannot be lifted off (B) Rim rent or incomplete tear (C) Outer fibers of cuff in incomplete tears can be lifted from the head of the humerus (D) Finger can palpate sulcus and irregularities on the humeral head through the thinned cuff (E) Longitudinal split in cuff will permit probe to be inserted into the side of the cuff also permitting visualization of the inner surface of the cuff (F) Blister is raised when instrument is passed laterally over the cuff (Redrawn, with modifications from McLaughlin)

1 Normally upon abduction of the arm in various planes of rotation the musculotendinous cuff passes under the coraco-acromial arch without a wrinkle on its superficial surface. However, if a rim rent is present as the arm is abducted a wrinkle or blister' forms at the site of the lesion as it approaches the falciform edge of the coraco-acromial ligament or edge of the acromion

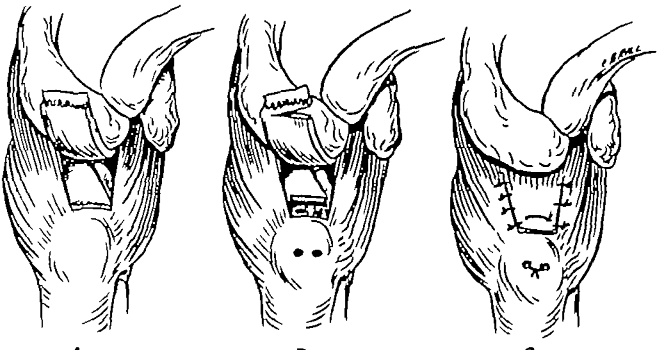

FIG 151 Repair of incomplete ruptures of the supraspinatus region of the cuff (A) A longitudinal incision is made parallel to the tendon fibers between the supraspinatus and the subscapularis tendons next a transverse incision is made extending posteriorly The length equals the width of the rupture. A second longitudinal incision is made parallel to the first. (B) The affected portion of the cuff is excised. A bony trough is made in the anatomic neck of the humerus. (C) The freshened end of the cuff is reattached by mattress sutures.

2 The blister can be demonstrated by passing a flat instrument laterally toward the tuberosities over the surface of the cuff (*Fig 150F*)

3 By grasping the affected cuff with a forcep it will be found freely movable on the humerus while the normal cuff on either side fails to show this degree of mobility (Fig 150C)

4 Visualization of the deep surface of the cuff through a small longitudinal incision through its entire thickness is justifiable if the afore-mentioned signs are present (Fig 150E)

A fifth test may be added to the above Simple palpation of a relatively normal *subacromial bursal floor will often disclose* thinning of the cuff pronounced irregularity of its deep surface, a sulcus and at times both sulcus and eminence (Fig 150D)

TECHNIC OF REPAIR OF LESIONS ON THE SYNOVIAL SIDE OF THE CUFF (MC LAUGHLIN) McLaughlin s transacromial approach provides adequate exposure of the subacromial region The incomplete tear of the cuff is first visualized by a longitudinal incision through the fibers of the coracohumeral ligament (between the subscapularis and the supraspinatus muscles) A transverse incision is then made through the whole thickness of the cuff extending posteriorly for a distance equal to the length of the incomplete tear As a rule the transverse limb of the incision terminates at the juncture of the supraspinatus and the infraspinatus tendons (Fig 151A)

A second longitudinal incision is made *beginning at the posterior edge of the transverse* incision, paralleling the first (Fig 151B) This mobilizes completely the affected region of the cuff The degenerated impaired portion of this mobile flap is excised transversely The remodeled end of

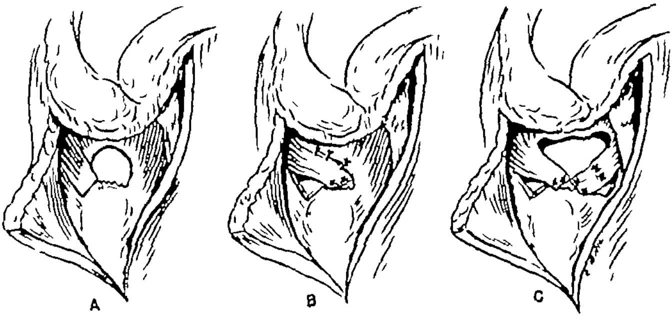

FIG 152 Method of repair of complete ruptures after Lawrence Jones (A) Site of tear (B) Repair effected by restoration of the efficiency of the central link of the cuff by utilizing a single flap cut from the infraspinatus portion of the cuff (C) In more extensive tears 2 flaps are cut one from the infraspinatus and the other from the subscapularis portion of the cuff The latter may not be sufficiently long to reach the desired site of reattachment into the greater tuberosity, in which case the tendon is lengthened by a strip of fascia lata.

the cuff should consist of healthy tendon fibers throughout its full thickness Next, a trough is made in the anatomic neck of the humerus, and the end of the healthy flap is anchored in it by means of mattress sutures passed through holes drilled through the lateral surface of the greater tuberosity The lateral margins of the flap are attached to the adjacent subscapularis and infraspinatus tendons by interrupted side-to-side sutures (Fig 151C)

Incomplete transverse tears on the bursal side of the cuff are treated similarly to those on the synovial side However tears within the substance of the cuff or superficial tears running parallel with the cuff fibers can be excised readily by elliptical incisions paralleling the tendon fibers Closure of the remaining gap is achieved by interrupted side-to-side sutures

Not infrequently incomplete tears particularly those affecting the bursal side of the cuff, are associated with pronounced secondary inflammatory changes in the subacromial bursa Such changes, as previously noted, comprise villous formation on the floor of the bursa thickening of the synovial walls and adhesions within the bursal sac In view of these findings recovery will be hastened and become more complete if the bursa is excised This is done routinely by the author

Moreover, to preclude impingement of the repaired cuff and greater tuberosity against the acromion and the coraco-acromial ligament, the osteotomized portion of the acromion always is removed, and the coraco-acromial ligament is divided close to its insertion into the medial edge of the acromion

2. **Complete Tears.** Numerous methods of repair have been described for complete lesions of the musculotendinous cuff In general, the rationale of these procedures is based on the concept believed to be responsible for the mechanism of the tear

Codman advocated end to-end suture of the torn tendon If the distal stub of the tendon was absent or frayed so it would not hold a suture the proximal end of the

tendon was sutured into the greater tuberosity This method was conceived on the premise that all primary tears are transverse tears and that the ultimate triangular or crescentic defect discernible in old cases is produced by retraction of the supraspinatus muscle

Both Wilson and Bosworth devised methods of repair which were based on Codman s concept They differ only in the manner of attachment of the torn cuff to the humerus The method described by McLaughlin is based on an entirely different concept of the mechanism of defect production, while Jones approach to the problem is based on the functional importance of various components of the musculotendinous cuff

Jones postulated that shoulder motion is the result of co-ordinated movements of two groups of muscles One unit the short rotators stabilizes the humeral head and the other stabilizes the glenoid He contended that simultaneous contraction of the capsular muscles resulted in a pull against their bony insertion into the humeral head and also a pull against one another through the medium of the fibrotendinous cuff in which the tendon fibers of all muscles are welded into one continuous sheath The central link of the various components of the cuff is the supraspinatus muscle whose weight is approximately one-seventh of the total weight of the four short rotator muscles In view of the relative weakness of this muscle Jones believed that its interruption in complete cuff lesions was not responsible for the loss of abduction He was also of the opinion that interruption of the central link of the conjoined cuff reduced the mechanical efficiency of the subscapularis muscle anteriorly and of the infraspinatus and the teres minor muscles posteriorly Jones procedure therefore tends to restore the functional continuity of the cuff but disregards the supraspinatus muscle (Fig 152)

McLaughlin contends that the defect noted in complete tears of the cuff is a combination of a transverse tear and a longitudinal split through the cuff usually starting at the anterior edge of the transverse tear Divergent forces of the subscapularis muscle, pulling anteriorly (and of the remaining rotators, pulling posteriorly), are responsible for the triangular or crescentic defect in the cuff (Fig 137) His method of repair attempts to restore the anatomic continuity and the mechanical efficiency of the cuff The high percentage of excellent results obtained with this procedure substantiates McLaughlin s concept and justifies his method

TECHNIC (MCLAUGHLIN) The essential features are excision of the peripheral margins of the defect to healthy vascular tissue and reduction of the defect by side-to-side repair up to but not beyond the point of tension and reinsertion of the retracted portion of the cuff into the humeral head, at whatever point it will reach without tension when the arm is at the side Although the technic varies in each case the aforementioned principles are applicable to all degrees of tears with retraction ranging from tears with only slight retraction to massive avulsion of the cuff with marked retraction as far as the level of the glenoid

The subacromial region is exposed through the transacromial incision An oblique osteotomy is done through the acromion beginning anteriorly at a point midway between the acromioclavicular joint and the lateral margin of the acromion and terminating at the lateral tip of the acromion Having defined the limits and the character of the tear its peripheral degenerated fibrotic margins are excised back to healthy vascular tendon tissue Generally, the tear is converted into a V-shaped defect whose apex points medially (Fig 153A)

A shoelace type of continuous suture (No 5 Deknatel is employed beginning at the apex of the opening Traction on the ends of the suture approximate the adjacent margins of the defect Suturing is continued in this fashion up to the point of tension—never beyond it—and so only a small V shaped hiatus remains Next the articular cartilage immediately below the remaining

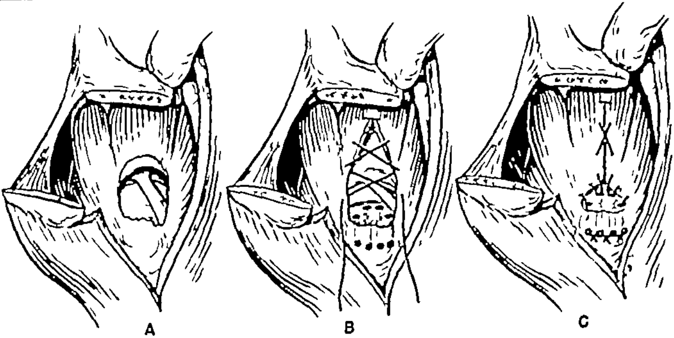

FIG 153 Method of repair of complete ruptures (after McLaughlin) (A) Rupture in cuff exposed through a transacromial incision the degenerated margins of the defect are excised back into healthy tissue. (B) Shoelace type of continuous suture beginning at the apex of the defect is used to approximate the freshened edges of the cuff (C) The edges are approximated up to the point of tension with the arm at the side a triangular hiatus usually remains in the cuff The articular cartilage of the head of the humerus just below the defect is removed, exposing raw bone. The cuff is reattached to the humerus by passing the ends of the continuous suture through drill holes, tying them on the outer surface of the greater tuberosity If necessary, additional mattress sutures may be added to attain better approximation of the edges of the cuff to raw bone

defect is removed exposing the raw subchondral bone Enough cartilage is removed to place the edges of the defect in contact with raw bone The two continuous sutures are then passed through drill holes and tied onto the outer surface of the greater tuberosity Occasionally additional mattress sutures may be necessary to secure the edges of the defect firmly against the new bony insertion (Fig 153B and C)

It is advantageous to discard the osteotomized portion of the acromion to divide the coraco-acromial ligament at its insertion into the medial edge of the acromion and, finally to excise as much bursal tissue as possible This favors the passing of the tuberosity and the musculotendinous cuff under the coraco-acromial arch without impingement and undue friction The deltoid muscle is sutured to the fascia and the periosteum over the remaining portion of the acromion No appreciable loss of deltoid efficiency has been demonstrable in cases so treated

POSTOPERATIVE MANAGEMENT This phase of the treatment is guided by the severity of the lesion and the willingness and the co-operation demonstrated by the patient Postoperative management must be supervised *at all times* by the surgeon in harmony with his knowledge of the lesion prior to repair and the type of repair which provide him with valuable guides to dictate how intense and rapid a restoration program may be instituted

Immediately following operation the arm is placed in balanced suspension until wound healing is completed (Fig 261) Gentle motion is allowed during this period After the wound is healed the patient is allowed out of bed and is started on a well regulated supervised program of gravity free pendulum exercises to be performed within the tolerance of pain—never beyond

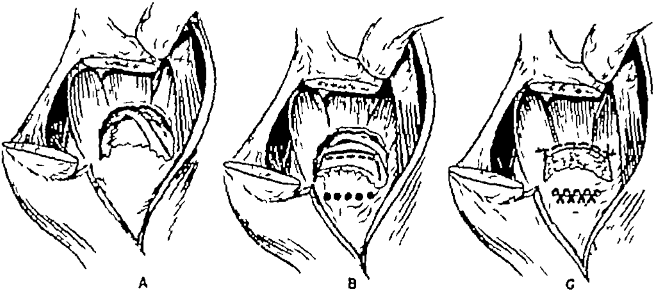

FIG. 154 Repair of massive avulsion of the cuff with advanced retraction (after McLaughlin) Approximation of the lateral edges of the defect may not be possible, freshened edge of the cuff is then attached to the humeral head at whatever point it reaches without tension (A) The transacromial incision adequately exposes the defect in the cuff (B) The edges of the cuff are freshened back to healthy tissue and the articular cartilage is removed from the head of the humerus to provide a raw bony bed. (C) The cuff is reattached to the raw bony surface by mattress sutures passed through drill holes and tied in the outer surface of the greater tuberosity

the point of fatigue Exercises should be performed for short periods (5 minutes) at frequent intervals (every hour on the hour) As pain subsides and strength returns active exercises are increased and wall-crawling exercises are added Active elevation of the arm is never permitted before three weeks. Usually it is safe to allow active elevation between the third and the seventh weeks depending upon the severity of the lesion and the security of the repair Resumption of light normal use is encouraged at once but its rate of increase always should be guided by the above factors

3 Massive Avulsion of the Cuff These lesions are treated by the technic described previously for complete tears with retractions The cuff in most instances can be secured at some point to the humeral head thereby providing a suspensory support for the head and also improving the efficiency of the rotator muscles Generally restoration of function is sufficient to justify the procedure. Rarely is it necessary to resort to arthrodesis of the glenohumeral joint In only one instance in which there was complete avulsion of the cuff which had retracted beyond the glenoid cavity was the author forced to do an arthrodesis In this case it was impossible to mobilize any part sufficiently to reinsert it into the humeral head Usually however while the cuff in massive avulsions lies between the glenoid and the humeral head it can be mobilized sufficiently to allow reinsertion into the head (Fig 154)

Theoretically a Nicola procedure in addition to the cuff repair should add further stability of the humeral head in cases of massive avulsions of the cuff However the author never has felt the need of this additional procedure None of the thirteen cases of massive avulsion of the cuff treated by McLaughlin s method showed any tendency toward subluxation of the humeral head.

4 Concomitant Lesion with Incomplete and Complete Tears of the Cuff

BICIPITAL TENOSYNOVITIS. The incidence of bicipital tenosynovitis accompanying tears of the musculotendinous cuff is greater

FIG 155 Multiple areas of ossification in the musculotendinous cuff of a male 26 years of age. The individual dislocated the shoulder 3 years prior to the taking of this roentgenogram At operation more heterotopic bone was demonstrable than the roentgenogram depicts. Note the scalloped defect in the superolateral aspect of the head of the humerus. It was impossible to excise the bone without removal of the greater portion of the cuff thereby seriously impairing the rotator and stabilizing mechanism of the glenohumeral joint.

than is generally realized It may be caused by the initial trauma or by secondary inflammatory changes in the bicipital sulcus and the impaired portion of the musculotendinous cuff bridging the groove. Pain and stiffness persist in many instances of cuff injuries, after the acute phase has subsided It has been the author s experience that in the majority of cases, the disability is not caused by an incomplete or mild complete tear of the cuff but by a bicipital tenosynovitis The nature of the syndrome varies with the severity of the lesion This observation has been confirmed at operation many times and is discussed fully in the chapter dealing with bicipital syndromes

TENDINITIS OF ROTATOR TENDONS Existing degenerative alterations in the cuff past middle age along with the inflammatory processes that are discernible after incomplete or complete tears of the cuff force one to concede that tendinitis does exist and that it may give rise to symptoms However, it has been proved conclusively that lesions of the cuff which do not materially impair the normal mechanics of the shoulder joint do not necessarily produce symptoms. Symptoms are manifest only when there is an actual impediment to smooth joint motion, such as impingement of the torn cuff and the greater tuberosity against the acromion or the coraco-acromial ligament during abduction or elevation of the arm It is obvious that tendinitis, per se is not the responsib'e lesion for the syndrome Mechanical obstructions to normal motion are the true etiologic factors Restriction of the normal arcs of motion, a characteristic feature of these lesions is responsible for vascular and lymphatic stasis, which, in turn are followed by fibrosis, contracture and shortening of the capsular elements, shortening of the rotator muscles and shortening adductor muscles of the shoulder The biceps tendon and sheath are also involved in this process and further restrict the joint motion. The clinical picture is now one of frozen shoulder It is interesting to note that a frozen shoulder never has been observed in association with a complete cuff tear Tendinitis is considered in more detail in the chapter on frozen shoulder and bicipital syndromes

Calcareous deposits are occasionally demonstrable in torn degenerated cuff fibers and osseous tissue may be discernible in the cuff in rare instances. These observations were also noted in several cadaver and post

FIG 156 Heterotopic bone formation in the cuff An acromioplasty was done and the extremity was treated with a sling followed by early mobilization

FIG 157 Hypertrophied subacromial bursa removed from the shoulder of an individual exhibiting a typical painful arc syndrome Exploration of the inner aspect of the cuff disclosed also an incomplete tear in the supraspinatus region which was repaired. The patient made an excellent recovery

mortem specimens. Such alterations are indicative of pronounced degenerative changes in the tendon fibers (Fig 155 and 156)

BURSITIS Subacromial bursitis does not exist as a primary entity It is always secondary to some other pathologic change in the adjacent tissues. The close proximity of the floor of the bursa to the superficial surface of the musculotendinous cuff renders it vulnerable to lesions involving this region. In all cases of complete tears of the cuff in the supraspinatus region and incomplete tears of the superficial fibers of this portion of the cuff the floor of the bursa reveals some degree of involvement. Severity of the alterations in the bursa is as a rule in direct ratio to the extent of the cuff impairment Once established bursal changes which comprise villi adhesions and thickening of the bursal walls will add further hindrance to joint movements The bursal tissues are richly supplied with sensory nerve fibers. Impingement of these tissues against the coraco-acromial arch elicits pain, thereby restricting motion On the basis of these observations it is justifiable to excise as much of the bursa as possible in surgical procedures in this region (Fig 157)

Exostoses. Exostoses may form on the tip of the greater tuberosity at the insertion of the supraspinatus tendon They may be concomitant lesions with a cuff tear or may occur following fracture of the tuberosity without tearing of the cuff (Fig 141) Bosworth reported an instance following sudden hyperextension of the arm Impingement of the bony mass against the acromion or the coracohumeral ligament elicits pain and a jog Radiographic examination in different positions will disclose the lesion. Excision of the exostoses is essential in order to relieve distressing symptoms.

TEARS CONCOMITANT WITH DISLOCATIONS FRACTURES AND FRACTURE DISLOCATIONS OF THE HUMERAL HEAD Rupture of the cuff is not an infrequent lesion accompanying dislocations fractures and fracture-dislocations of the humeral head They are discussed fully in the chapter dealing with these traumatic lesions.

5 **Acromioplasty** There is now general agreement that removal of the lateral por

tion of the acromion has no harmful effects It should be done routinely in all repairs for both complete and incomplete cuff tears Removal of portions of the acromion eliminates all abnormal impingement of the impaired cuff against the acromion and minimizes normal friction Therefore, the procedure favors early restoration of joint function McLaughlin describes two types of osteotomies through the acromion (1) an oblique osteotomy which starts anteriorly midway between the acromioclavicular joint and the lateral margin of the acromion and extends laterally to emerge at the tip of the acromion and (2) an anteroposterior osteotomy which starts at the same point anteriorly as the oblique osteotomy and extends directly posteriorly (Fig 338) The latter is utilized to obtain maximum exposure of the cuff, whereas the former gives slightly less exposure but a better cosmetic result

The deltoid muscle which is stripped from the lateral margin of the acromion is reattached to the fascia and the periosteum over the remaining medial portion of the acromion Deltoid power is not impaired by this procedure

If deemed necessary the entire acromion may be removed without ill effect, provided that the coracoclavicular ligaments are intact

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5

Frozen Shoulder and Bicipital Syndromes

FROZEN SHOULDER
BICIPITAL TENOSYNOVITIS
BICIPITAL TENOSYNOVITIS
ASSOCIATED WITH TRAUMA
BICIPITAL TENOSYNOVITIS WITHOUT TRAUMA
CORACO-ACROMIAL LIGAMENT
CORACOHUMERAL LIGAMENT
RUPTURE OF THE BICEPS TENDON
PROXIMAL RUPTURES
TRAUMATIC DISLOCATION

HISTORICAL SURVEY

The enigma of the "painful stiff shoulder" has been the source of much speculation by workers interested in this problem. Many and varied pathologic lesions have been recorded in the literature as probable etiologic factors. Nevertheless there is a general feeling that the true causative agents of this syndrome and the developmental steps culminating in partial or complete loss of scapulohumeral motion as yet have not been uncovered.

Duplay (1896) was the first investigator to focus our attention on the extra-articular tissues of the scapulohumeral joint as a possible source of pain and limitation of motion. He was of the opinion that inflammation of the subacromial bursa was the responsible pathologic lesion for the above clinical features and coined the term "scapulohumeral periarthritis." The medical profession quickly adopted this term which soon came to embrace a large and heterogeneous group of cases whose only common denominators were pain and stiffness in the region of the shoulder joint. It is astonishing to note with what reluctance the term "periarthritis" is being discarded for it provides a designation for a host of inexplainable shoulder lesions.

Calcareous deposits in the rotator cuff chiefly in the supraspinatus tendon were finally recognized as capable of producing this syndrome. As the result of the meticulous and comprehensive studies of Painter (1907), Baer (1907), King and Holmes (1927), Mumford and Martin (1931) and Dickson and Crosby (1932) this group of cases was taken out of the heterogeneous classification of "periarthritis" and became recognized as an unequivocal clinical entity. However, credit must be given to Codman (1934) for the clarification of the pathogenesis of this entity. He also set forth the principles of therapy which we employ at the present time. Codman demonstrated that the lesion developed primarily in the degenerated fibers of the fibrotendinous cuff and that symptoms arose only when the synovial lining of the subacromial bursa became involved. These observations have been verified many times and now there is general agreement on this point.

Calcareous tendinitis is responsible for pain and stiffness in the scapulohumeral joint in approximately 50 per cent of the individuals with painful and stiff shoulders (McLaughlin 1944). It becomes apparent therefore that a host of individuals remained without adequate explanation of their malady. Again credit goes to Codman who extracted from this residue another group of cases. His exhaustive studies on the

rotator cuff of the shoulder joint gave us another undisputed, crystallized clinical entity—rupture of the supraspinatus tendon—which is now recognized as a common causative agent of this symptom complex

In spite of these contributions, there remained still a large number of cases which had neither calcareous deposits in the fibrotendinous cuffs nor rupture of the supraspinatus tendons Meyer (1921 1926, 1928 and 1930) was the first observer to point to the long head of the biceps brachii muscle as a possible source of disorders about the shoulder joint These studies were made on shoulder joints of cadavers He described degenerative and attritional lesions comprising fraying shredding fasciculations and tearing of the fibers of the biceps tendon Some specimens exhibited partial or complete dislocation of the tendon out of the bicipital groove in several shoulder joints the intracapsular portion of the tendon was absent while the proximal end of the extracapsular portion had attained a bony insertion in the region of the lesser tuberosity He attributed these lesions to the following causes (1) contact of the tendon with a supratubercular ridge when present (2) roughening and irregularities of the floor of the sulcus and (3) contact of the tendon with cartilaginous margins of the humeral head or with the lesser tuberosity in those instances of partial or complete dislocation He was of the opinion, furthermore that these alterations were the result of using the upper extremity in a position of abduction and external rotation

Gilcreest (1926) provided clinical data in support of rupture of the long head of the biceps tendon In a comprehensive investigation of 100 cases he recognized an "acute" and a latent" rupture of this structure and recorded that the "latent" group was often unrecognized and erroneously diagnosed as bursitis arthritis sprain etc This work was followed by another study published in 1936 on Spontaneous Dislocation of the Tendon of the Long Head of the Biceps Brachii"

Although vague references had been made to tenosynovitis of the long head of the biceps brachii muscle, both in this country and abroad it was not until 1932 that Pasteur (1933) correlated the observations of Meyer and the clinical picture characterized by pain and stiffness in the shoulder joint He described the syndrome teno-bursite as a new clinical entity and believed it to be the responsible pathologic disorder underlying periarthralgias and ankylosis of the shoulder joint Pasteur was the first observer to associate tenosynovitis of the long head of the biceps brachii muscle with the frozen shoulder' Schrager confirmed Pasteur's observations and described, for the first time in American literature, tenosynovitis as a definite clinical entity These contributions were followed by many comprehensive articles in American literature all of which emphasized the close relationship between lesions of the biceps tendon and the syndrome characterized by pain and stiffness in the shoulder joint (Abbott, L C, and Saunders J B Tarsy J M, Mosely H F, Hitchcock H H, and Bechtol C O)

Lippmann (1944) described adhesive tenosynovitis as the cause of frozen shoulder" He reported twelve cases which, on exploration exhibited an inflammatory process of the long head of the biceps and its sheath with no involvement of any of the periarticular structures Although he did not demonstrate the lesion, he was of the opinion that the limitation of motion was due to extension of the inflammatory process, involving the biceps tendon into the joint producing adhesions which in turn fixed the intracapsular portion of the tendon to the capsule and the articular surface of the humerus He recorded that upon releasing the peritendinous adhesions full motion was restored readily without forceful manipulation

Codman was of the opinion that the biceps tendon and its sheath played only a minor role if any in the production of shoulder symptoms He wrote "Personally, I believe that the sheath of the biceps tendon is less

FIG 158 (*Left*) Characteristic features of a patient with a left frozen shoulder The patient s general health is below par she has been a victim of bronchiectasis for many years. Note the relation of the axis of the shaft of the humerus to that of the spine of the scapula forming approximately a right angle This relationship is maintained during all movements of the arm and is more clearly discernible in roentgenograms taken during different stages of elevation of the arm

FIG 159 (*Right*) Same characteristic features as those pointed out in Figure 158 except that the patient s general health is better Roentgenograms of both extremities were made during different stages of elevation (Figs. 160-161)

apt to be involved than are the other structures I have never proved its involvement in a single case I think that the substance of the tendon of the supraspinatus is the most often involved. He believed that the pathology of frozen shoulder was essentially tendinitis of the rotator tendons

From the above survey it is obvious that much work remains to be done before clarification of this symptom complex is attained

FROZEN SHOULDER

INTRODUCTION

The observations recorded in this chapter referable to frozen shoulder and bicipital tenosynovitis were made on a clinical investigation of 83 cases of which 56 were investigated surgically Correlation of these findings with those noted in the study on degenerative lesions of the shoulder joint permitted one to make some logical deductions referable to the causes and the pathogenesis of frozen shoulders.

CLINICAL FEATURES

Frozen shoulder is a definite clinical entity There is a characteristic cycle of events It usually occurs in individuals after 40 years of age (only 1 case in this series was under 40) the greatest number are found between 50 and 60 years more women (67 per cent) than men are affected and it is a relatively common disorder in patients afflicted with cardiovascular, pulmonary or metabolic diseases (Fig 158)K

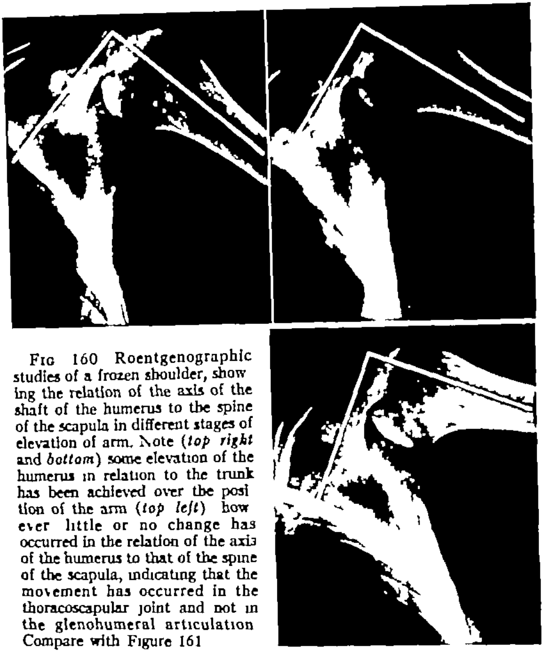

FIG 160 Roentgenographic studies of a frozen shoulder, showing the relation of the axis of the shaft of the humerus to the spine of the scapula in different stages of elevation of arm. Note (*top right* and *bottom*) some elevation of the humerus in relation to the trunk has been achieved over the position of the arm (*top left*) however little or no change has occurred in the relation of the axis of the humerus to that of the spine of the scapula, indicating that the movement has occurred in the thoracoscapular joint and not in the glenohumeral articulation Compare with Figure 161

The syndrome may develop after some form of injury to the shoulder on the other hand the onset may be insidious without injury In the early phase of the disease there are varying degrees of pain and stiffness in the shoulder Increased activity accentuates the pain which is usually localized over the anterolateral aspect of the shoulder Frequently, the pain radiates to the anterior aspect of the middle of the upper arm and occasionally to the flexor surface of the forearm. A common complaint is pain during the night which frequently interferes with sleep Tenderness always can be elicited by making pressure over the bicipital groove or rolling the biceps tendon under the examiner s thumb There is a steady increase in the severity of the symptoms while the arcs of painless motion in the glenohumeral joint become progressively smaller until there is little or no motion in the joint Both the deltoid and the spinatii muscles exhibit varying degrees of spasm and atrophy The extremity is held at the side in a position of internal rotation Generally a few degrees of free painless motion are demonstrable in the glenohumeral joint in the anteroposterior plane Occasionally compression of the belly of the biceps brachii muscle evokes pain Not infrequently all the cardinal signs and symptoms of a scalenus anticus yndrome are present and may

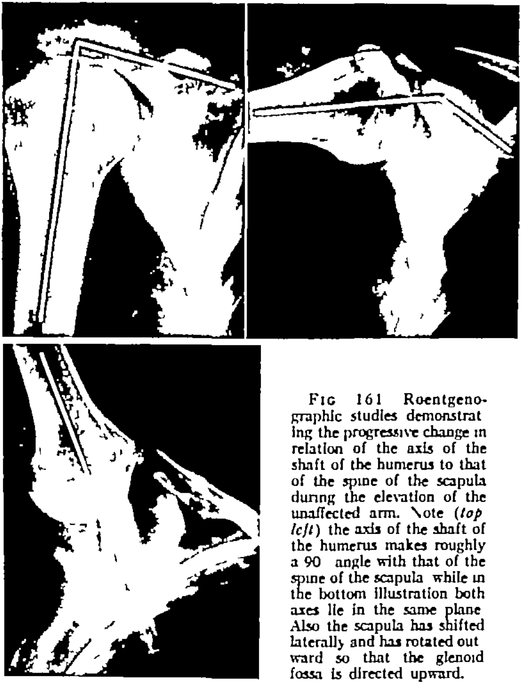

Fig 161 Roentgenographic studies demonstrating the progressive change in relation of the axis of the shaft of the humerus to that of the spine of the scapula during the elevation of the unaffected arm. Note (*top left*) the axis of the shaft of the humerus makes roughly a 90 angle with that of the spine of the scapula while in the bottom illustration both axes lie in the same plane Also the scapula has shifted laterally and has rotated outward so that the glenoid fossa is directed upward.

confuse the clinical picture Clinically there now exists a fibrous ankylosis of the scapulohumeral joint It is interesting to note that in some instances when all motion is lost pain may become bearable and in fact may disappear in other instances there is intractable pain (Figs 160 and 161)

At this point it must be pointed out that pain is the most significant feature of the syndrome Although it is true that there exists pronounced restriction of movements in the scapulohumeral joint most patients ascribe their disability to the pain rather than to loss of movements

The clinical course which frozen shoulders pursue is variable and unpredictable because it may terminate at any stage of its development or remain static for months and even years before regression of the syndrome begins In many instances after a variable period of time pain subsides and slow restoration of function begins A normal shoulder joint is not regained in all instances many individuals exhibit per

manent weakness and some residual loss of movements in all directions in the scapulohumeral joint As stated in many articles on the subject, it is erroneous to believe that complete and spontaneous recovery within 6 months to 3 years always occurs Three patients in this series exhibited painful stiff shoulders for 5, 6 and 8 years, respectively, with no indication of regression of the malady

Etiology and Pathogenesis

(1) Muscular inactivity is the causative agent responsible for frozen shoulder Any cause which restricts scapulohumeral movement produces muscular inactivity (2) Bicipital tenosynovitis, as will be shown subsequently, is the most common etiologic factor, some other causes are (3) contusions sprains dislocations, fracture of the shoulder, and injuries to the musculotendinous cuff Restriction of scapulohumeral motion coincident to treatment of injuries of the upper extremity at a distance from the region of the shoulder as fractures of the forearm and wrist, also produces inactivity of the shoulder musculature which may terminate in a frozen shoulder

As a result of functional inactivity, regardless of the cause muscle tone is diminished, and muscle atrophy supervenes The normal delicate balance of the metabolic processes of the tissues is disturbed and there follows a slowing down of the circulation and venous and lymphatic stasis. All soft tissues adjacent to and comprising the musculotendinous cuff become saturated with serofibrinous exudates which provide the fibrin responsible for formation of capsular synovial, fascial intermuscular and intramuscular adhesions A low grade chronic inflammatory process ensues which involves all the tissues affected The process begins in all tissues simultaneously, and not in one specific area Findings consistent with a chronic inflammatory process are readily discernible in microscopic sections made from the different areas of the musculotendinous cuff the biceps tendon and the subacromial bursa (Fig 162) On the other hand, functional activity reverses the above process and restores circulation and joint function

The shoulder joint is unique in that its anatomy renders it susceptible to changes which produce stiffness Its articular capsule is loose and redundant, when the arm is in the sling position numerous nictitating folds are formed in the inferior and anterior aspects of the glenohumeral joint (Fig 15) Moreover, as the short rotator muscles cross the capsule to their respective points of insertion in the head of the humerus, they provide large surface areas on which serofibrinous fluid may accumulate This is also true of the large surface areas between the outer and the inner muscular sleeves (the deltoid forms the outer sleeve, the spinati and the subscapularis muscles the inner sleeve). Finally, the subscapularis recesses and subacromial bursa are suitable sites for accumulation of serous exudates

Frozen shoulders develop only when the afore-mentioned phenomenon occurs in shoulder joints exhibiting profound degenerative alterations in the synovialis, the musculotendinous cuff and the biceps tendon In the presence of these changes the process progresses until there is firm fixation of the scapulohumeral joint by extra-articular and intracapsular adhesions[1] All structures lose their elasticity and those on the anterior aspect of the glenohumeral joint become shortened It was interesting to observe the effect of these changes on the coracohumeral ligament It is converted into a tough, inelastic contracted cord of fibrous tissue extending from the coracoid process to both tuberosities of the head of the humerus (Fig 18) This structure, together with the shortened subscapularis muscle, functions as strong checkreins to

[1] The term "intracapsular adhesions" is used to designate adhesions between the nictitating folds of the synovialis, particularly in the anterior and inferior aspects of the joint and in those binding the synovial side of the capsule to the inferior surface of the head of the humerus.

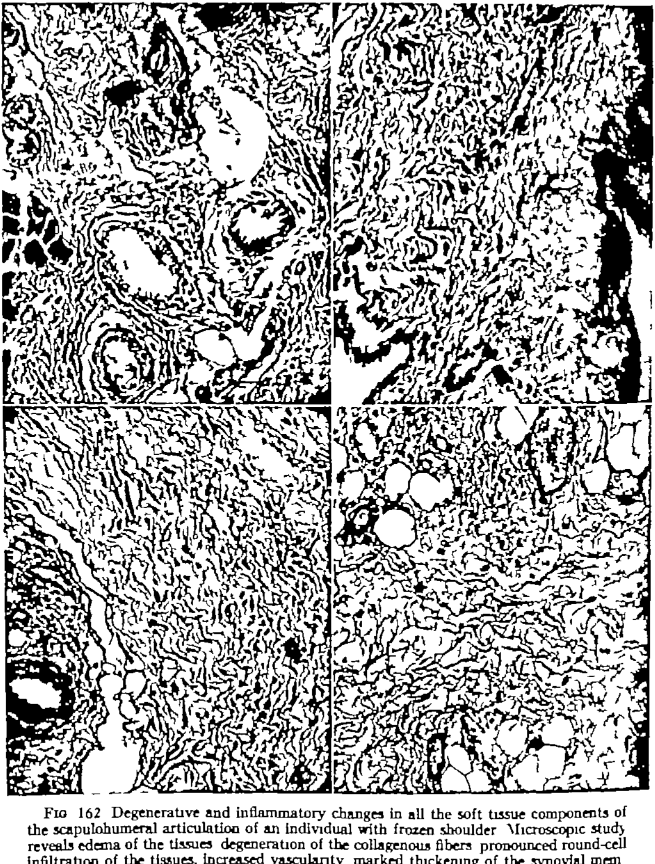

FIG 162 Degenerative and inflammatory changes in all the soft tissue components of the scapulohumeral articulation of an individual with frozen shoulder Microscopic study reveals edema of the tissues degeneration of the collagenous fibers pronounced round-cell infiltration of the tissues, increased vascularity marked thickening of the synovial membrane and evidence of increased fibrosis These findings are consistent with a low grade chronic inflammatory process superimposed on degenerative alterations in the soft tissue elements affected (*Top left*) A microscopic section through the walls of the subacromial bursa (× 245) (*Top right*) Microscopic section through the coracohumeral ligament (× 245) (*Bottom left*) Microscopic section through the supraspinatus region of the musculotendinous cuff (× 245) (*Bottom right*) Microscopic section through the subscapularis tendon (× 245)

FIG 162 (*Continued*) Microscopic section through the biceps tendon. Note the marked thickening of the synovial membrane and increased cellular elements in this tissue (× 250)

external rotation, while the infraspinatus and the teres minor muscles restrict internal rotation All cases explored demonstrated varying degrees of involvement of the tendon tendon-sheath gliding mechanism of the biceps tendon Bicipital tenosynovitis is a concomitant lesion of all frozen shoulders, its implication may be primary or secondary

It has been demonstrated amply that gross degenerative lesions occur in all individuals after the fourth decade that microscopic lesions occur after the third decade that these alterations increase in intensity with each subsequent decade and finally that in the later decades they may assume profound proportions (Fig 66) This explains the occurrence of frozen shoulders in individuals past 40 years of age and its rarity before this age period Moreover constitutional states which tend to increase the severity of degenerative alterations in tissues render patients afflicted with such disorders still more vulnerable It is common knowledge that frozen shoulders are encountered frequently in debilitating disorders as cardiac, pulmonary and metabolic diseases

Bicipital tenosynovitis plays a major role in the symptomatology and the course pursued by frozen shoulders Involvement of the tendon tendon sheath gliding mechanism may be primary or secondary nevertheless, regardless of its origin, once it is established it gives rise to pain in the shoulder, especially when the extremity is put through certain arcs of motion Because of the resulting pain, further functional inactivity results, a situation which favors circulatory impairment in the soft tissues and formation of adhesions The location of the pain over the bicipital groove and tenderness elicited on pressure over this area and over the biceps tendon forces one to conclude that bicipital tenosynovitis is the prime causative factor responsible for pain both in the early and in the late phases of the disease This has been proved many times in cases in this series, in which, after excision of the intracapsular portion of the tendon and transplantation of the proximal end of the extracapsular portion to the coracoid process, there was dramatic and instantaneous relief of pain

Clinical assessment reveals that in many cases of frozen shoulders after a period of pain and disability, pain disappears, and shoulder function is slowly regained It is reasonable to assume that in these cases the inflammatory process subsides muscle spasm is relieved, adhesions undergo resolution, and muscular activity is restored, which in turn tends to restore normal circulation to the affected tissues. In other instances pain and stiffness persist. Pain is the outstanding feature and results from involvement of the biceps tendon and the tendon sheath A cure can be affected in these cases only by obliteration of the tendon tendon sheath mechanism nature achieves this in some instances by anchoring the tendon to the shaft of the humerus be-

low the lesser tuberosity By so doing the pain factor is eliminated, and restoration of joint function can begin Such a clinical course is illustrated by Case J F (p 109) In still another and smaller group of cases nature fails to eliminate the biceps tendon gliding mechanism, therefore, spontaneous recovery does not occur, and pain and stiffness persist

It appears that the ultimate result depends directly on the degree of degenerative alterations existing in the structure comprising the scapulohumeral joint This is borne out by the clinical observation that in individuals under 40 years of age in whom only minimal changes are observed and in whom the circulation of the tissue is excellent, frozen shoulders rarely occur following muscular inactivity in individuals of later decades who are in good general health frozen shoulders develop, but spontaneous recovery occurs in most of them (Case M W) however in individuals past middle life afflicted by some debilitating disease which tends to accentuate physiologic degenerative lesions, protracted pain and shoulder dysfunction are the rule (Case T R.)

Treatment

Successful management is governed by careful selection of cases and by instituting the correct therapy for each case Whenever possible the causative or initiating factor responsible for the frozen shoulder should be determined In many instances elimination of this cause will promote relief of muscle spasm rapid return of normal muscular activity and restoration of joint function. For example calcareous tendinitis may be the underlying cause in such instances simple excision of the pathologic irritative material will start the sequence of events which will lead to recovery Also bicipital tenosynovitis may be the cause (Case W S) Treatment directed toward effecting a cure of this lesion in turn will alleviate pain and initiate restoration of scapulohumeral motion.

Early Stages of the Disease

Pain and pronounced muscle spasm are the principal features of this stage.[1] If possible these individuals are best treated by complete bed rest, sedatives to relieve pain, continuous hot fomentations to the shoulder and active exercises in the supine position within the painless arcs of motion. Blocking of the cervical sympathetic ganglia with 10 or 15 cc. of 1 per cent procaine provides considerable comfort and relieves muscle spasm After from 7 to 10 days the arm is rested in a sling, but pendulum exercises are encouraged on a prescribed time schedule For example, the arm is exercised every hour, each exercise being done 10 or 12 times always within the painless arcs of motion (Fig 238) Later, the sling is discarded and crawling up-the-wall and pulley exercises are added Such a regimen will produce surprisingly excellent results in a goodly number of patients within 8 to 10 weeks In patients who refuse a period of bed rest, repeated blocking of the cervical sympathetic ganglia (the procedure is done 3 or 4 times every 4 or 5 days) is a valuable adjunct to the therapy described above Even in the face of a well planned and well executed regimen many cases progress to the later stage

Later Stage of the Disease

In the later stage pain is usually less and loss of scapulohumeral motion is caused by intracapsular and extracapsular adhesions shortening of the rotator and the adductor muscles and muscle spasm Pain and adhesions limit the range of motion to a few degrees (10° to 20°) in the anteroposterior plane beyond this arc pain is accentuated All cases explored in this study disclosed varying degrees of involvement of the biceps tendon gliding mechanism. In some

[1] With complete muscular relaxation under anesthesia these shoulders disclose considerable freedom of motion in the scapulohumeral joint, indicating that muscle spasm (and not adhesions and soft tissue contractures) is responsible for the restricted range of movements.

the tendon was bound down by firm dense adhesions, in others it was enmeshed in a network of filmy adhesions These findings conform to those of Hitchcock and Bechtol The author is of the opinion that in these cases recovery is retarded because of (1) the pain factor which precludes motion of the glenohumeral joint beyond a certain restricted arc and (2) the mechanical obstruction to movements provided by adhesions implicating the biceps tendon Recovery can be hastened and the patient rehabilitated by eliminating the above two factors. This is done simply by severing the biceps tendon at the supraglenoid tuberosity and transplanting it to the coracoid process Hitchcock and Bechtol first advocated removing the intra articular portion of the tendon The procedure herein described differs from the one described by these workers only in that the tendon is anchored to the coracoid process instead of to the shaft of the humerus

Operative Technic

(See Treatment of Bicipital Tenosynovitis)

Manipulation for Frozen Shoulders

Manipulation is mentioned only in order to condemn it In spite of the fact that many investigators have pointed out repeatedly the futility and the dangers of this procedure many victims are still being subjected to the maneuver As the result of some striking observations noted under direct vision while manipulation procedures were carried out one is forced to conclude that gentle manipulation is impossible for the end results are invariably the same

In 8 patients, the affected shoulder joint was exposed through a splitting incision of the anterior deltoid In all instances upon external rotation of the extremity tears of varying degrees were noted in the substance of the subscapularis tendon and its lower muscle fibers inserting into the humeral shaft In 2 individuals the subscapularis tendon was completely avulsed from the lesser tuberosity and the tear extended proximally into the fibrotendinous cuff for 1 and 1½ inches, respectively Upon abduction of the arm, similar transverse tears were observed in the fibrous capsule along the inferior aspect of the humeral neck In 3 instances, the inferior articular surface of the humeral head came into view through the tears in the capsule One individual, in whom a manipulation had been done 3 months prior to the procedure done under direct vision, sustained a fracture through the surgical neck of the humerus Such observations serve to emphasize the hopelessness of such a procedure In this series 7 patients had had manipulative treatment In all, there was present still a frozen shoulder Three of these patients volunteered the information that following the manipulative procedure their pain had become lessened considerably, and they could move the affected shoulder through a greater arc of motion Examination of these individuals revealed that the scapulohumeral joint was frozen to a degree comparable with a bony ankylosis They had even lost the few degrees of motion in the anteroposterior plane which is demonstrable so frequently in patients with frozen shoulders All motion was in the thoracoscapular joint The completeness of the lack of glenohumeral motion undoubtedly accounted for the freedom from pain

Case Reports

Case M W female aged 42 in good health, sustained a fracture of the middle of the shaft of the humerus when she fell down a flight of stairs The fracture was reduced and the extremity was immobilized in a hanging cast After 10 weeks the cast was removed at which time the patient noted that she had considerable stiffness in the right shoulder She volunteered the information that for several weeks prior to removal of the cast she was aware of a dull aching pain in the shoulder which radiated into the neck and into the anterior aspect of the upper arm Following immobilization the extremity was placed in a sling for a

period of 2 more weeks, during which time she was allowed to exercise her elbow, wrist and fingers, but restoration of function in the shoulder joint was disregarded

When the patient was seen 12 weeks after injury to the humerus she had a frozen shoulder The arm was held at the side in a position of internal rotation There were only about 15° or 20° of motion in the anteroposterior plane and about 10° or 15° abduction at the scapulohumeral joint All other motion was entirely thoracoscapular She was started on an intensive program of pendulum exercises which were followed by crawling up-the wall and pulley exercises Within a period of 8 weeks this patient had regained complete restoration of function in the shoulder joint

DISCUSSION This is a typical example of a patient who developed a frozen shoulder following fixation of the extremity in the sling position but because of her general good health and good muscular tonicity succeeded in attaining rapid return of movements by restoration of muscular activity.

Case W S., female aged 42, had a long history of pain and stiffness in the left shoulder which had been initiated approximately 18 months prior to her admission to the hospital by acute and excruciating pain in the anterolateral aspect of the shoulder which radiated into the anterior aspect of the arm and into the posterior cervical region Pain had been lessened by irradiation but considerable pain and stiffness persisted Stiffness had become more pronounced within the last 3 months

Examination 18 months after the initial onset disclosed that the patient had a frozen shoulder except for about 15 of motion in the anteroposterior plane and about 15 of motion in abduction in the scapulohumeral joint. There was marked tenderness throughout the entire anterior and lateral aspects of the joint capsule particularly under the tip of the acromion process Radiographic examination revealed a large calcareous deposit more or less diffuse in nature involving a large area of the supraspinatus and the infraspinatus regions of the cuff At operation a subacute inflammatory process implicating the entire cuff was noted The biceps tendon was not explored Large quantities of calcareous material were curetted out of the supraspinatus and the infraspinatus tendons, which also disclosed advanced degenerative changes There was diffuse infiltration of the material throughout the tendon fibers of the affected cuff Multiple puncture of the affected portions of the cuff was performed in order to increase the hyperemia and to favor absorption of the remaining calcified material which was not accessible The subacromial bursa was found thickened injected and loculated The thickened walls of the bursa were excised Following operation the patient was immediately put on a regimen of pendulum exercises followed by crawling up-the-wall and pulley exercises Restoration of function in the scapulohumeral joint was almost complete at the end of 8 weeks, there was still about 15° residual limitation of motion in abduction external rotation was possible to 50°, and the patient was completely free of pain

DISCUSSION This is an instance in which calcareous tendinitis initiated muscular activity which, in turn was responsible for a generalized fibrositic process resulting in a frozen shoulder Removal of the irritant which in this case was calcareous material within the substance of the musculotendinous cuff was sufficient to eliminate pain and initiate muscular activity which in turn restored function to the scapulohumeral joint

Case B T female aged 45 became aware of a dull boring ache in the anterolateral aspect of the left shoulder 7 years before the pain gradually increased in intensity was aggravated by motion and relieved by rest It was worse at night interferring considerably with her rest. She noticed a gradual stiffening of the left shoulder The range of free painless motion became less and less until she was able to get her hand to her head only with great diffi

culty Two years after the onset the patient's arm was manipulated under anesthesia and put on a regimen of physical therapy and exercises In spite of intensive treatment the patient failed to regain any motion, although her pain did become somewhat less Thirteen months after the first manipulation, the arm was again manipulated, and another regimen of physical therapy and exercises was instituted similar to that prescribed following the first manipulation. Pain and stiffness persisted This was followed by a course of irradiation to the shoulder without any relief of symptoms

Upon examination 7 years after the onset of the symptom complex, the patient presented a very pathetic picture She was an *undernourished apprehensive, asthenic individual* complaining of constant pain in the shoulder also she had formed the habit of taking large doses of sedatives in order to obtain some rest and sleep. There was *considerable atrophy of all the musculature* of the shoulder girdle particularly the spinatii and the deltoid muscles. The arm was held in the sling position Only 5° or 10 of motion could be demonstrated in the anteroposterior plane no motion in abduction was demonstrable in the scapulohumeral joint actively or passively Pressure over the anterior aspect of the shoulder joint, particularly over the intertubercular sulcus elicited excruciating tenderness. Rolling of the biceps under the finger also gave rise to considerable pain Radiographic examination revealed nothing of any significance except that the head rode high in the glenoid cavity and all the bones of the shoulder girdle revealed pronounced decalcification At operation the biceps tendon was found to be firmly adherent within the bicipital groove and also adherent to the undersurface of the joint capsule Numerous dense adhesions enmeshed the entire tendon within the groove The subacromial bursa was obliterated completely There was shortening of all the anterior structures on the anterior aspect of the joint particularly the subscapularis muscle and the *inferior portion of the joint capsule* The entire musculotendinous cuff presented the picture of a low grade inflammatory process

The biceps tendon was severed at the supraglenoid tubercle and transplanted to the coracoid process Relief of pain was instantaneous in this patient Active motion was started on the third day Following the operation there was progressive increase in the degree of motion At the end of 14 weeks the patient was able to abduct the arm actively 160° When last seen the patient still had 10° or 15° residual restriction of abduction and external rotation However, she was perfectly happy free of pain, and showed general physical and mental improvement (Fig 171)

Discussion This case demonstrates that when the pain factor produced by bicipital tenosynovitis (which is always present in a well-established case of frozen shoulder) is removed, restoration of muscular activity *can proceed and is followed invariably by* increased function at the scapulohumeral joint.

Case T R. male aged 52 sustained severe second-degree burns of the anterior and posterior aspect of the trunk as a result of a gasoline explosion During the course of treatment both arms were bandaged to his side for a period of 6 weeks For the following 4 weeks no attention was paid to scapulohumeral motion, the patient was not encouraged to move the extremities When seen 4 months after his injury the patient complained of severe pain and stiffness in the left shoulder and moderate pain and stiffness in the right shoulder

Physical examination disclosed a very thin asthenic individual and marked atrophy of the musculature of both shoulder girdles The left side disclosed a typical frozen shoulder only a few degrees of motion in the anteroposterior plane and about 10° of abduction were demonstrable in the scapulohumeral joint Pressure over the intertubercular groove and the biceps tendon elicited exquisite tenderness Examination of the right shoulder showed from 20° to 30° re

striction of motion in elevation and 45° of external rotation Pressure over the inter tubercular sulcus and over the biceps tendon evoked tenderness The above findings were consistent with a bicipital tenosynovitis in the right shoulder it also became apparent that sooner or later a frozen shoulder would develop In addition to a frozen shoulder, on the left there was a concomitant bicipital tenosynovitis

Both shoulders were operated upon in each instance the biceps tendon was transplanted to the coracoid process Relief of pain was instantaneous and within 8 weeks the patient had complete restoration of function within the right shoulder and within 4 months was able to abduct the left shoulder to 150 , to rotate it externally 45°, and to put his hand in his hip pocket on the affected side without discomfort

Discussion This is a typical example of a frozen shoulder following immobilization of the extremity due to extrinsic causes with secondary involvement of the biceps tendon in a fibrositic process affecting all the soft tissues about the shoulder On the left we had a frozen shoulder in its late stages while on the right side a frozen shoulder in its incipient stage was demonstrable

BICIPITAL TENOSYNOVITIS

Introduction

Critical clinical assessment of incidences of painful and stiff shoulders reveals that involvement of the long head of the tendon of the biceps brachii muscle is by far the most common etiologic factor responsible for the symptom complex. This concept is not in agreement with that of many workers interested in shoulder disorders (Codman Simmonds etc.) however it has been substantiated many times by visualization of the subacromial area in patients exhibiting the syndrome Also this investigation forces one to conclude that disorders of the biceps tendon are frequent precipitating causes of frozen shoulder in a great majority of cases

General Observations

The clinical material in this investigation fell into two groups In Group 1 the symptoms were initiated by trauma to the shoulder joint, while in Group 2 the onset was insidious with no definite trauma to the part Group 1 revealed more men to be afflicted (72 2 per cent) than women (27.8 per cent) Group 2 disclosed a greater prevalence among women (52.3 per cent) than men (47 7 per cent) In this series the right shoulder was involved in 50 5 per cent, the left in 49 5 per cent, and both shoulders in 3.3 per cent The average age of patients in the first group was 41 years, while in the second group it was 45 years Regardless of the groups in which they fell no individuals with bicipital tenosynovitis under 30 years of age developed a frozen shoulder Frozen shoulders were usually encountered in individuals between 40 and 60 years of age. Many of these individuals were below par in general physical fitness They were apprehensive emotionally unstable and not a few were victims of chronic debilitating diseases such as pulmonary cardiovascular and gastro-intestinal diseases. There was a close parallelism between the high incidence of frozen shoulders and the presence of debilitating factors

Bicipital Tenosynovitis Associated with Trauma

General Observations. In bicipital tenosynovitis associated with trauma the usual history is one of pain and stiffness in the region of the shoulder joint following either severe or minor injuries In this study the severe injuries encountered in the second and the third decades were simple dislocations of the glenohumeral joint fractures of either tuberosity surgical neck fractures and dislocations associated with fractures through the greater tuberosities In the older cases (after the fourth decade), the most common injuries were fractures of the tuberosities fractures through the anatomic neck, with or without displacement and fracture

dislocations The symptom complex not infrequently follows minor injuries, such as a fall on the point of the shoulder or on the flexed elbow joint, forcing the humerus upward Strenuous exercises, such as tennis or shoveling snow, may initiate the symptoms

Clinical Features Resulting From Minor Traumata. The outstanding symptom is pain in the anterolateral aspect of the shoulder This pain is often projected to the region of the insertion of the deltoid muscle and to the belly of the biceps brachii muscle. In severe forms, the pain radiates posteriorly to the region of the scapula and to the posterolateral aspect of the neck As a rule motion is restricted in all directions, however, a certain range of free voluntary motion is always present If the arcs of this range are exceeded, the pain may become intense and severe. Abduction and external rotation, and backward flexion and external rotation usually accentuate the pain Varying degrees of muscle spasm about the shoulder joint are present, all depending upon the severity of the lesion Such spasm may be demonstrable in the deltoid, the trapezius and the scalenus muscles and at times in the forearm muscles Pain may be more pronounced at night and interferes with sleep Upon lying on the affected side, pressure on the point of the shoulder accentuates the pain

The most constant physical finding, and a very significant one, is exquisite tenderness on pressure over the bicipital groove Of the several diagnostic tests for bicipital tenosynovitis the one described by Lippmann is the most dependable Lippmann noted that with the arm actively flexed to a right angle the long biceps tendon can be palpated about 3 inches from the joint. If the tendon at this point is displaced to one side and then suddenly released the patient experiences a sudden twinge of pain in the bicipital groove. It was also observed that with the elbow actively flexed exquisite tenderness was elicited in every case by firmly rolling the long tendon of the biceps under the examiner's thumb Yergason's maneuver conveys no information in the majority of the cases

Roentgenographic examination at this time reveals no information, because the pathologic changes affect the soft tissue structures in the bicipital groove and not the osseous elements of the groove

In most instances, these acute minor lesions pursue a clinical course which is fairly constant If the affected extremity is put to rest for several days, the intensity of the symptoms subsides gradually, while the range of motion increases steadily until complete and painless motion is restored

Occasionally, the acute stage may be followed by a long protracted course of disability of varying intensity Although there is always a certain range of free and painless motion, if the limits of this motion are exceeded, pain is felt in the anterolateral aspect of the shoulder This is particularly true of abduction and external rotation and backward flexion and external rotation The syndrome is accentuated by activity and relieved by rest Not infrequently pain is referred to the belly of the biceps brachii muscle, to the flexor surface of the forearm and to the scapular region Pressure over the bicipital groove and rolling the biceps tendon under the examiner's thumb elicits intense pain Such a cycle may continue for many months Its intensity varies with the extent of the inflammatory process involving the tendon sheath and the tendon In one case, such a symptom complex had existed for 3 years

Occasionally, in individuals past the fourth decade there is a steady increase in the severity of the symptoms, while the arcs of painless motion become progressively smaller until there is little or no scapulohumeral joint motion. The spinati and the deltoid muscles exhibit varying degrees of atrophy The extremity is held at the side in a position of internal rotation As a rule a few degrees of free painless motion is always demonstrable in the anteroposterior plane Clinically the picture now is one of fibrous ankylosis of the scapulohumeral

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of the bicipital groove was noted a large hemorrhagic area It appeared as if blood from a higher level had gravitated distally beneath the synovialis of the floor of the groove Upon closer inspection it was noted that the uppermost fibers of the subscapularis tendon for a distance of ¼ inch, had been torn from their bony attachment on the lesser tuberosity The torn fibers were frayed, thickened and hemorrhagic. It was apparent that this was the site of bleeding By splitting the fibrotendinous cuff and capsule, the intracapsular portion of the biceps tendon came into view It appeared normal in every respect except that the distal portion of the synovialis was greatly injected. The bicipital groove was of normal depth and configuration but it revealed a well formed supratubercular ridge

The duration of symptoms in the other 6 cases explored ranged from 4 months to 3 years. In Cases C W, P T and W F, the syndrome was rather mild Motion was normal in all directions, but twinges of pain were felt at the ends of the arc of abduction and external rotation and backward flexion and external rotation

At operation the tendon sheath in each was found to be thickened, injected and edematous numerous long filmy adhesions were disclosed between the tendon and the sheath In spite of these frail structures, the tendon-sheath gliding mechanism was impaired only slightly The intracapsular portion of the tendon was free and appeared grossly normal the extracapsular portion was narrowed The transition between the two was abrupt. In all a well-defined supratubercular ridge was demonstrable in W F the inner border of the biceps tendon had made a trough in the uppermost fibers of the subscapularis tendon No other abnormalities referable to the grooves were noted.

In R M J S and P S, the syndrome was more severe Although pain was an outstanding feature motion in the shoulder joint was restricted and responsible for great disability In all instances, exploration of the shoulder joint exhibited the sheath to be reddened, thickened and edematous The tendon tendon sheath mechanism was obliterated by well formed vascular adhesions, binding the tendon to the groove. The extracapsular portion of the tendon was thinned, frayed and had lost its sheen

In Cases R M and J S, the intracapsular portion of the tendon was slightly thickened and edematous, but free Full passive motion could be demonstrated readily in these cases, in spite of the fact that the tendon was bound to the groove by adhesions which permitted only very limited motion of the tendon in the groove On the other hand, in Case P S, the intracapsular segment of the tendon was adherent to the inner surface of the capsule in the region of the coracohumeral ligament Full passive motion in this case was impossible to attain, for intracapsular adhesions acted as mechanical barriers to the excursion of the humeral head on the tendon. Complete motion was attained, however, after the tendon was freed from the inner surface of the capsule

Four cases aged 38 47, 58 and 62 with minor injuries to the shoulder joint exhibited a progressive bicipital syndrome which was interrupted by surgical intervention before the phase of complete loss of glenohumeral motion was reached

The subacromial bursa and the fibrotendinous cuff appeared grossly normal The biceps tendon was found adherent to the sheath by numerous filmy red adhesions of varying firmness and density The process extended into the joint binding the distal end of the intracapsular portion of the tendon to the inner surface of the capsule After the tendon was freed from the sheath and capsule, the range of motion in all shoulders was increased greatly, however, complete motion in abduction and external rotation could not be attained without some force It was noted for the first time that there had occurred mild contracture of the subscapularis muscle and of the redundant capsule along the inferior aspect of the neck Abduction and external rotation put these structures on a stretch as more force was

joint or a frozen shoulder It is of interest to note that in some instances, when all motion is lost in the scapulohumeral joint pain becomes more bearable and it even may disappear *In other instances there is* intractable pain

OPERATIVE FINDINGS A close parallelism exists between the gross pathologic findings and the duration and the severity of the ill ness Within a few hours after injury the sheath of the biceps tendon is markedly in jected red and edematous thereby con stricting the tendon within the sheath Hemorrhagic areas may be found beneath the synovialis lining the groove actually, tearing of some of the fibers of the sub-scapularis tendon from the lesser tuberosity on the joint side may be demonstrated At this stage the process has the appearance of an acute inflammation as yet no defi nite adhesions are formed Such findings were exhibited clearly in a shoulder joint which was explored 48 hours after injury (Case C R.)

Cases with a longer duration exhibit more advanced alterations of the tendon and the tendon sheath. Adhesions varying from fine frail filmy structures to firm dense tough bands of fibrous tissues may be found between the sheath and the tendon Tendon and sheath may be adherent to the transverse humeral ligament and to the floor and the side of the groove Occasionally the process may extend into the joint cavity and involve the distal end of the intracap-sular portion of the tendon binding it to the inner surface of the capsule in the region of the coracohumeral ligament

Adhesions within the limits of the groove which obliterate the tendon tendon sheath gliding mechanism or bind the tendon to the groove do not mechanically limit mo-tion. At operation full motion is readily demonstrable without freeing the tendon from the sheath or groove However if the tendon is adherent to the inner side of the capsule then a definite mechanical barrier exists to free excursion of the humeral head on the biceps tendon Complete motion is restored only after the tendon is freed from this attachment Well formed supratubercu lar ridges frequently are found diminishing the depth of the groove and often distorting *its configuration* In spite of the extensive involvement of the biceps tendon that might be present, changes consistent with those of a frozen shoulder are seldom encountered in young individuals

CASE REPORTS AND PERTINENT OBSERVA TIONS Seven cases all under 40 years of age, with minor injuries were explored. One patient (C R.) for investigative reasons was explored 48 hours after the initiating trauma

Case C R. male aged 23 while serving a tennis ball felt a sudden snap which was associated with excruciating pain in the right shoulder He was unable to continue the game because all motions of the shoul der joint were painful During the night his shoulder throbbed like a toothache " The following day he was seen in the out patient clinic.

Examination disclosed only a few degrees of passive painless forward and backward flexion Attempted abduction passively or actively was accompanied by severe pain in the anterolateral region of the shoulder joint Pain was referred also to the anterior aspect of the upper arm pressure over the bicipital groove elicited great tenderness. Intense pain was experienced when the tendon of the long head of the biceps muscle was rolled under the examiner s thumb

At operation the following day 48 hours after the injury the shoulder joint was ex plored No pathologic alterations were noted referable to the subacromial bursa The fibrotendinous cuff was intact and exhibited grossly a normal appearance Upon splitting the transverse humeral ligament and tendon sheath the biceps tendon bulged into the operative field as if it were released sud denly from great pressure. Its synovial sheath was thickened red and friable it presented macroscopically the characteris-tics of an acute inflammatory process. Be neath the synovial lining of the entire length

of the bicipital groove was noted a large hemorrhagic area It appeared as if blood from a higher level had gravitated distally beneath the synovialis of the floor of the groove Upon closer inspection it was noted that the uppermost fibers of the subscapularis tendon for a distance of ¼ inch, had been torn from their bony attachment on the lesser tuberosity The torn fibers were frayed thickened and hemorrhagic It was apparent that this was the site of bleeding By splitting the fibrotendinous cuff and capsule, the intracapsular portion of the biceps tendon came into view It appeared normal in every respect except that the distal portion of the synovialis was greatly injected The bicipital groove was of normal depth and configuration, but it revealed a well formed supratubercular ridge.

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applied, fine tears were observed in the superficial fibers of the subscapularis tendon and the capsule These findings are not in agreement with those of Lippmann who maintains that unrestricted motion is attained when the biceps tendon is freed from adhesions within the bicipital sheath and groove

It was apparent that the afore-mentioned pathologic changes (the bicipital tenosynovitis contracture of the subscapularis muscle *and redundant fibrous capsule*) constituted the early phase of a process which, if it progressed would eventually terminate *in extra articular and intra articular fibrous* ankylosis of the scapulohumeral joint Such changes were not noted in younger individuals

Interpretation of Operative Findings and Their Correlation with the Clinical Picture. From the afore-mentioned observations it is obvious that the essential pathologic alteration is an inflammatory process in the sheath of the long biceps tendon and in the tendon itself The degree and the extent of the inflammatory process governs the character of the bicipital syndrome Case C R is representative of a very early lesion and it demonstrated that the morbid pathology in cases following severe sudden muscular exertion is one of tearing and stretching of the affected tissues followed by hemorrhage and edema Pain is due to actual tearing of synovial periosteal and fascial tissues while motion is restricted by the associated reflex muscle spasm about the shoulder joint and by pain If treated adequately by rest graduated exercises and physical therapy the inflammatory process retrogresses gradually and complete restoration of function can be anticipated in the majority of the individuals in the younger age group

In a few instances the illness becomes protracted the patients develop mild syndromes similar to those of cases C W P T and W F Here, the pathologic alterations are not unlike the 'tendovaginitis stenosans' described by Dequervain (1895) Essentially, the tendon sheath is thickened and it constricts the tendon within, thereby preventing the smooth, free motion of the tendon Filmy adhesions, present between the sheath and the tendon do not restrict the range of motion they only add to the mechanical difficulty

Further progression of the same process results in an obliteration of the tendon tendon sheath gliding mechanism. The tendon and the sheath are bound together by *well formed vascular adhesions of varying* thickness and toughness or together they may be found adherent to the groove and *occasionally to the inner aspect of the capsule* in the region of the coracohumeral ligament Clinically the outstanding features noted in patients with such morbid anatomy are restriction of motion and exquisite tenderness over the bicipital sulcus and the biceps tendon As previously stated during joint motion adhesions in the groove result in traction on the surrounding periosteal and fascial tissues thereby producing pain The range of motion is restricted not because of the presence of adhesions in the groove but because of pain and muscle spasm produced when certain arcs of motion are exceeded (Cases R M and J S) However if the tendon is adherent to the inner surface of the capsule motion is restricted also by a definite mechanical barrier which makes it impossible for the humeral head to glide proximally on the long biceps tendon (Case P S)

Frozen shoulders were not encountered in individuals under 40 years of age regardless of the severity the extent and the duration of the bicipital tenosynovitis. This observation leads us to assume the presence of some other factor or factors besides tenosynovitis before a frozen shoulder develops. Moreover the Case of P S demonstrated that a certain range of free motion is possible in the glenohumeral joint even when the biceps tendon is bound to the inner aspect of the capsule We must admit that the range is greatly restricted by the afore-mentioned mechanical barrier nevertheless

the clinical picture in no way simulated that of a frozen shoulder

As previously noted *in the majority of* instances of acute tenosynovitis, the process gradually subsides with rest to the part, and free full motion is restored *On the other* hand, the process may become static for many months with periods of exacerbations, then motion gradually increases, and pain diminishes until normal glenohumeral motion is attained Knowing the morbid pathology in these cases, the pathologic sequences underlying the clinical events can be reconstructed readily The tendon tendon sheath mechanism is either restored by gradual dissolution of the binding adhesions or the tendon attains a bony anchorage in the bicipital groove *Obliteration of the* tendon tendon sheath gliding mechanism does not bring about freedom of pain To attain complete and painless *motion, the* tendon must not have a fibrous attachment to the humerus but a bony one, and there must *be no pull on the surrounding tissues* This observation was noted in many cases of this series and will be discussed when the *treatment of these lesions is considered*

Clinical Features Resulting From Severe Traumata. In young individuals bi*cipital tenosynovitis associated with severe* traumatic lesions in the region of the shoulder joint is encountered more frequently than hitherto believed In this series, 8 instances of bicipital tenosynovitis following severe trauma in individuals under 30 years were encountered It was associated *more* frequently with depressed fractures of the greater tuberosity than with any other type of lesion One case revealed on exploration an incomplete tear of the supraspinatus tendon and 3 cases a complete tear At first the syndrome generally is obscured by symptoms of the more obvious lesion Involve*ment of the long head of the biceps tendon* and its sheath is manifest by persistence of pain in the anterolateral aspect of the shoul*der and by restriction of motion* long after the time necessary for healing of bone and oft tissue has elapsed

Examination discloses, in the acute states, spasm of the short rotator muscles, the *trapezius* and the scalenus muscles Depending upon the severity and the duration of the symptom complex, atrophy of the *spinatii and the deltoid* muscles is presen in varying degrees Pressure over the bicipital groove always elicits great tenderness *In every instance, rolling the* long tendon of the biceps muscle under the examiner s thumb produces intense pain Usually, *there is observed* a certain range of active painless motion If the arcs of this range are exceeded, severe pain is felt in *the region of the bicipital groove Motions* which put the biceps tendon on a stretch as abduction and external rotation or backward *flexion and external rotation are accom* panied by excruciating twinges of pain

In some instances, carefully scrutinized *roentgenograms give valuable information* referable to the bicipital groove In this series two of the individuals, who had sustained *a fracture* through the base of the greater tuberosity, exhibited on roentgenographic study considerable new bone forma*tion* which encroached upon the outer margin of the bicipital groove (Fig 163) Axial views of the humeral head may reveal spurs *on the lesser tuberosity* Although these observations are not diagnostic, they at least provide presumptive evidence of lesions of the biceps tendon when they are associated with a bicipital syndrome

Operative Findings. Essentially the *pathologic* change is an inflammatory process, involving the tendon tendon sheath mechanism. Its severity and extent vary *depending in a large measure upon the char*acter of the concomitant lesion

Fractures in the region of the bicipital groove *may change the configuration of the* groove thereby impairing the normal gliding apparatus of the biceps tendon (Figs 163 165) Generally, *involvement of the* tendon and the tendon sheath in these instances surpasses that observed in cases without osseous disruption *The tendon* tendon sheath mechanism may be obliter

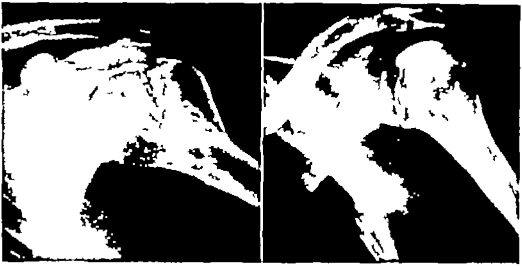

FIG 163 (*Left*) Depressed fracture of the greater tuberosity which healed with pronounced new bone formation changing the configuration of the bicipital groove. At operation, in addition to the above osseous changes the biceps tendon was found adherent to the distorted groove by dense firm adhesions (case L. P)

FIG 164 (*Right*) Unusual depressed fracture of a portion of the head of the humerus resulting from shock therapy in a female, aged 52 years In spite of immediate mobilization and physical therapy, a frozen shoulder developed At operation the intertubercular sulcus was found to be narrowed and irregular and the constricted biceps tendon was enmeshed in filmy vascular adhesions.

ated by dense firm vascular adhesions which bind the entire mass to the groove The tendon is frayed shredded and thinned only a thin fibrous band in the groove may represent the remains of the tendon This process extends into the capsule and may bind the distal end of the intracapsular portion of the tendon to the inner surface of the capsule As a rule the groove is shallow and narrow Bony spurs are frequent findings on the inner and the outer boundaries and occasionally in the floor of the groove With depressed fractures of the greater tuberosity new bone formation along the upper and outer margin of the bicipital sulcus is a common finding These bony excrescences not only decrease the depth and the width of the groove but actually dig into the substance of the tendon during joint motion (Fig 166)

CASE REPORTS AND PERTINENT OBSERVATIONS Four individuals with depressed fractures of the greater tuberosity were explored In all the tendon was found adherent to the sheath and the groove and to the inner surface of the capsule in the area of the coracohumeral ligament. At operation full motion could not be demonstrated after the biceps tendon was freed in the groove it could be accomplished only after the tendon was released from the inner surface of the capsule

In spite of the extensive involvement of the biceps tendon and the tendon sheath frozen shoulders were not encountered in this younger age group

Case J C male aged 30 wrenched his shoulder while wrestling Pain was localized in the anterolateral aspect of the shoulder and radiated into the forearm It was more intense at night and any activity aggravated his symptoms He was treated by physical therapy for a year without improvement Four years after the injury he was seen in an Army hospital complaining of constant pain in the anterolateral aspect of the shoulder joint. The pain radiated anteriorly to the belly of the biceps brachii muscles and into the posterior region of the scapula

FIG 165 Other types of osseous lesions implicating the bicipital groove and the bicipital tendon tendon sheath mechanism, which were responsible for the bicipital syndrome in this series. In both instances, implication of the biceps tendon was confirmed at operation. Both developed frozen shoulders.

Examination disclosed moderate atrophy of the spinati muscles There were a few degrees of painless active voluntary motion in the anteroposterior plane Any attempts of abduction passively or actively accentuated the pain Pressure over the greater tuberosity and over the bicipital groove elicited exquisite tenderness Roentgenographic examinations exhibited no pathologic alterations A tentative diagnosis of rupture of the supraspinatus tendon was made, and an exploratory operation of the shoulder was recommended

At operation, it was noted that the walls of the subacromial bursa were thickened and injected The floor of the bursa was red and had lost its luster Although no complete rupture of the fibrotendinous cuff in the region of the insertion of supraspinatus tendon was found the cuff in this region was very thin permitting the underlying bone of the greater tuberosity to be readily palpable The thin frayed portion of the cuff was resected thereby bringing the distal end of the intracapsular portion of the biceps tendon into view Inspection of the tendon disclosed it to be free in the joint however, it was injected, thickened and had lost its sheen Fine adhesions were found between the under surface of the tendon and the floor of the upper end of the intertubercular groove. These findings were consistent with a tenosynovitis yet their significance at this time was not fully appreciated No exploration of the tendon within the groove was carried out In the belief that thinning, fraying and shredding of the supraspinatus tendon were the lesions responsible for the symptom complex, the impaired portion of the tendon was excised The healthy end of the supraspinatus tendon was sutured, without difficulty to the greater tuberosity in the conventional manner

In spite of intensive physical therapy no demonstrable improvement in the patient's symptoms or range of motion was noted 8 months after operation Pressure over the bicipital groove at the level of the tuberosities elicited great tenderness Rolling the biceps tendon under the examiner s thumb produced severe pain. Attempts at abduc

tion and dorsal flexion and external rotation accentuated the pain A diagnosis of bicipital tenosynovitis was made At operation the bursal walls were found to be greatly thickened the bursa was loculated The About an inch of the distal portion of the intracapsular tendon was firmly adherent to the inner surface of the capsule in the region of the coracohumeral ligament the tendon could be freed only by sharp dissec-

FIG 166 (*Left*) Specimen obtained from a cadaver in which there is evidence of a depressed fracture of the anatomic neck and the head of the humerus. The upper portion of the intertubercular sulcus has been completely obliterated and is filled in with numerous bony excrescences. The inferior surface of the corresponding biceps tendon exhibited advanced degenerative changes. (*Right*) Specimen obtained from a cadaver which had sustained a fracture through the surgical neck. Note the complete obliteration of the bicipital groove and marked irregular new bone formation In this specimen the extracapsular portion of the biceps tendon was found attached to this bony mass. The intracapsular portion was absent

fibrotendinous cuff was intact the only evidence of repair was the presence of several black sutures which were removed Upon splitting the transverse humeral ligament the biceps tendon was found to be firmly attached to the roof of the ligament and to the floor of the groove by firm dense adhesions. The tendon was narrowed injected and roughened By splitting the musculotendinous cuff through the outer fibers of the coracohumeral ligament as far as the apex of the glenoid cavity the intracapsular portion of the tendon was plainly visualized tion Free full passive motion was possible after it was released from the inner surface of the capsule The remainder of the tendon appeared thickened red and edematous. The tendon was severed close to the supraglenoid tubercle and was withdrawn from the joint cavity The edges of the fibrous capsule and cuff and the transverse humeral ligament were approximated by interrupted fine silk sutures About an inch of the biceps tendon was removed for histologic study and the end was then fixed to the tip of the coracoid process Relief of pain in this indi-

vidual was almost dramatic. Two weeks after operation he was able to abduct the arm actively to 110° without pain, 3 weeks later abduction was possible to 160°, and 10 weeks later he had complete and painless motion in the shoulder joint

Three other cases (W P, S T and R M) disclosed a complete tear of the supra spinatus tendon associated with a bicipital tenosynovitis In width, the tears measured approximately ½ in, ⅝ in and 1 in re spectively In each instance, the biceps ten don was extensively involved the tendon tendon sheath mechanism was obliterated by numerous adhesions, and the tendon was adherent to the under surface of the capsule. As in the case of J C, full range of motion was possible only after the tendon had been released from the inner surface of the capsule in the region of the coracohumeral ligament. No attempt was made to repair the defects in the supraspinatus area of the fibrotendinous cuffs In all 3 instances the biceps tendon was transplanted to the cora coid process. All made an uneventful recovery and there was complete restoration of painless motion in from 8 to 10 weeks

Study of these cases revealed many perti nent observations It became apparent that lesions of the biceps tendon may be associ ated with tears of the musculotendinous cuff Although Codman was of the opinion that partial or incomplete tears of the supra spinatus tendon (tears on the joint side of the supraspinatus tendon) were the most common causative lesions responsible for painful and stiff shoulders these cases demonstrated that involvement of the biceps tendon may play an even more important role From this study it is reasonable to assume that tears of the supraspinatus ten don are compatible with good shoulder func tion provided that the other rotators are intact and capable of fixing and depressing the humeral head in the glenoid cavity dur ing abduction and elevation of the arm These cases also demonstrated emphatically that mechanical impairment of motion is due to adhesions between the biceps tendon and the inner surface of the capsule Fur thermore, following Hitchcock and Bechtol, it was noted that by removing the entire tendon from the joint cavity and transplanting it to some other point, the patients were relieved immediately of pain, and free painless, shoulder motion was regained rapidly

Case L P., a male, aged 37, sustained an injury to the right shoulder when he fell out of a weapon carrier His arm was placed in a plaster shoulder spica for 12 weeks After a year of physical therapy, he still com plained of pain and stiffness in the right shoulder When the patient was seen 2 years after the injury, the pain was constant, and all motions of the shoulder joint accentu ated the pain It was most severe at night, especially if he rested on the affected shoul der He localized the pain at the insertion of the deltoid muscle and in the anterior aspect of the upper arm. Tingling and numbness was occasionally felt in the forearm and the hand along the course of the ulnar nerve

Examination disclosed advanced atrophy of the spinatii muscles and moderate atrophy of the deltoid muscle. Although he com plained of pain, he was able to abduct the arm voluntarily to 60° beyond this arc, he experienced severe twinges of pain causing him to drop the arm to the side Motion in the anteroposterior plane was free if he did not exceed 45° forward or dorsal flexion. With the arm at the side 50° of active and passive painless external rotation was present Pressure over the bicipital groove evoked great tenderness, a similar response was obtained when the biceps tendon was rolled firmly under the examiner s thumb Pain was elicited at the root of the neck when pressure was made in the supra clavicular space over the scalenus anticus muscle This maneuver accentuated the pain in the ulnar aspect of the forearm

Roentgenographic study disclosed an old healed depressed fracture of the greater tu berosity (Fig 163) Considerable irregu larity was demonstrable over the superior surface of the tuberosity and along the

FIG 167 Intracapsular portion and a small segment of the extracapsular portion of the biceps tendon removed from the shoulder (case L. P cf Fig 163) The tendon is attenuated in its middle and thickened at either end the constricted portion was firmly bound down in a narrowed irregular intertubercular sulcus.

lateral margin of the intertubercular groove

A diagnosis of bicipital tenosynovitis with an associated scalenus anticus syndrome was made.

Exploration was carried out through an anterior muscle-splitting incision The subacromial bursa was found to be obliterated completely the subdeltoid fascia was adherent to the greater tuberosity and to the outer surface of the musculotendinous cuff Considerable irregular new bone formation was noted over the superior surface and along the lateral margin of the intertubercular groove Bony spurs projected from the lateral wall of the groove The configuration of the groove was distorted. By splitting the transverse humeral ligament the fibrous capsule and the coracohumeral ligament the extracapsular and intracapsular portions of the biceps tendon were visualized clearly The tendon was found to be bound firmly by dense adhesions to the floor and the roof of the intertubercular groove Moreover that portion lying in the groove was reduced in thickness and presented no trace of a synovial lining Beginning at the level of the tuberosities and extending upward into the joint for 2 cm the tendon was adherent to the undersurface of the capsule in the region of the coracohumeral ligament Sharp dissection was necessary to free the tendon from its bed of fibrous tissue (Fig 167)

Gross inspection of the musculotendinous cuff revealed no pathologic alterations. Before freeing the tendon the arm could be abducted passively 90 A definite mechanical restriction was felt if the patient attempted to exceed this arc It was noted that as the arm came up to 90 the hypertrophied greater tuberosity abutted against the coraco-acromial ligament No increase in range of motion was noted when the tendon was freed from adhesions in the groove but when it was released from the inner surface of the joint capsule the arm could be abducted fully however, the coraco-acromial ligament became taut as the greater tuberosity passed under it. It was apparent that in this instance the coraco-acromial ligament was also a barrier to free abduction of the arm

The biceps tendon was severed close to the supraglenoid tubercle and withdrawn from the joint It was then anchored to the tip of the coracoid process The excess new bone over the greater tuberosity was removed with an osteotome The coraco-acromial ligament was divided close to the inner border of the acromion process and the margins of the coracohumeral ligament and the transverse humeral ligament were approximated with fine silk sutures.

Motion was started on the third postoperative day There was an immediate and progressive increase in the range of painless motion so that at the end of the third week abduction was possible to 130 Eight weeks after operation motion was complete and painless in all directions. All symptoms indicative of a scalenus anticus syndrome disappeared

This case emphasizes the possibility of the existence of a scalenus anticus syndrome with lesions of the biceps tendon Although the syndrome is as a rule a secondary phenomenon it may assume such prominence that the primary lesion may be obscured. Again it was noted that adhesions in the groove are only of significance in that they make tension upon the surrounding periosteal and fascial tissues thus producing pain and muscle spasm which restrict motion they are not mechanical barriers to free motion This is substantiated by the

clinical observation that once the biceps tendon has attained a bony anchorage to the shaft of the humerus, either by surgical intervention or spontaneously, pain disappears, and restoration of function is assured On the other hand, as previously mentioned, adhesions binding the tendon to the inner side of the capsule in the region of the coracohumeral ligament not only cause pain and muscle spasm but also restrict the ex cursion of the humeral head on the biceps tendon during shoulder motion

Three other cases (T C., V M and B D) with depressed fractures of the greater tuberosities and an associated bicipi tal syndrome were explored Pathologic findings, management and response were similar to those recorded in the case of L P It was significant to note that, regardless of the extensive involvement of the biceps ten don in this younger age group no instance of frozen shoulder was encountered

Severe injuries about the shoulder joint are not uncommon in individuals past the third decade If adequately treated, it is common knowledge that such injuries are compatible with good shoulder function However, regardless of the efficacy of treat ment, there are many instances in which pain and stiffness of the shoulder joint per sist. This is especially true of lesions in the region of the bicipital groove, such as frac tures through the tuberosities, depressed or comminuted fractures of the humeral head and fractures through the anatomic neck Involvement of the biceps tendon may be primary or secondary to changes in the con figuration of the bicipital groove. The ill ness may pursue several different courses it may be similar to that recorded in the cases of J C and L P after many weeks it may retrogress gradually while motion steadily increases until full free motion is attained or the syndrome may progress until there is complete loss of scapulohumeral motion

It was noted in this study that severe lesions did not necessarily predispose one to the development of a frozen shoulder On the other hand the general physical fitness of the patient appeared to be an important deciding factor In this series, 6 individuals (4 females and 2 males, all over 50 years of age), following fractures of the humeral head, developed a bicipital syndrome which terminated in a frozen shoulder All 6 were below par physically, also, they were apprehensive and emotionally unstable

Any lesion of the upper end of the hu merus which disrupts the normal configura tion of the bicipital groove may initiate a bicipital tenosynovitis In this age period there were 3 cases with a depressed fracture of the greater tuberosity, one with a frac ture through the base of the lesser tuber osity with inward displacement of the fragment 4 with fracture of the greater tuberosity and dislocation of the humeral head, 1 with fracture through the anatomic neck, and 1 with a depressed fracture of the humeral head All these cases were explored, and involvement of the long tendon of the biceps was demonstrable As previously stated, 6 of these developed frozen shoul ders. In 3 individuals (Figs 164 and 165) aged 52, 57 and 49 respectively, the bicipital syndrome developed and terminated in a frozen shoulder, regardless of the fact that every precaution was taken to mobilize the shoulder joint as early as possible

Codman was of the opinion that depressed fractures of the greater tuberosity always were associated with traumatic tendinitis of the rotator tendons, which in turn was responsible for pain, stiffness and protracted disability of the shoulder He completely overlooked the long head of the biceps ten don as a causative agent in these instances He failed to appreciate the significance of a distorted irregular bicipital groove in the production of bicipital tenosynovitis, which may initiate processes responsible for frozen shoulders in the older individuals

Bicipital Tenosynovitis Without Trauma

Bicipital syndromes initiated by or fol lowing trauma have been considered thus far in this presentation There are, however

a far greater number of individuals with clinical pictures identical with those described without definite histories of injury These individuals, like those previously discussed fall into two groups a younger age group under 30 years of age, and an older age group over 30 years of age The distinguishing feature between the two is that frozen shoulders are more prone to develop in the latter than in the former group

Younger Age Group As a rule the onset is an insidious one A mild ache is noted in the anterolateral aspect of the arm and twinges of pain are felt at the limits of normal arcs of motion Not infrequently pain is projected to the anterior aspect of the upper arm and to the insertion of the deltoid muscle Pain is accentuated by increased activity and is relieved by rest The arcs of abduction and external rotation and backward flexion and external rotation may be decreased Increased pain at night is a common complaint The most significant physical findings are tenderness revealed on pressure over the bicipital groove and also on rolling the long head of the biceps tendon under the examiner s thumb

The clinical course of the illness is very unpredictable it may remain in a static state neither progressing or retrogressing for many months on the other hand it may disappear completely for varying periods of time only to reappear again In one individual in this series the duration of the syndrome was 11 years

Three individuals when the arm was abducted and rotated externally felt a definite snap in the shoulder which was accompanied by lancinating pain in the bicipital area They could produce the snap voluntarily In one patient both shoulders were so afflicted

In this investigation frozen shoulders were not encountered in the younger age group. One patient aged 31 developed a frozen shoulder However the duration of her illness was 11 years during which time she had a rather free range of scapulohumeral motion pain was experienced only at the limits of this range

Operative Findings. Seven patients in this younger age group were explored No significant findings were noted referable to the subacromial bursae and musculotendinous cuffs In all, the biceps tendon and its sheath disclosed alterations similar to those in the cases of C. W , P T and W F , (p 153) which changes were consistent with tenovaginitis In two shoulders the groove was shallow and a pronounced supratubercular ridge was present. Three patients with snapping shoulders revealed some noteworthy findings In one patient there was present an unusually high supratubercular ridge and a shallow groove The biceps tendon was displaced to the inner side of the ridge and lay on the lesser tuberosity in a fascial sling made up of the uppermost fibers of the subscapularis tendon. Both biceps tendon and tendon sheath were covered by frail, red filmy adhesions the sheath was reddened, thickened and edematous Although the other two patients with snapping shoulders failed to demonstrate such a prominent supratubercular ridge, a definite ridge was present, and the bicipital grooves at the level of the tuberosities were shallow In one of these the biceps tendon was found displaced completely out of the groove and had made for itself a bed in a fascial sling on the inner side of the lesser tuberosity

Comment Analysis of this group leads one to conclude that certain configurations of the bicipital sulcus may be the underlying factors responsible for tenosynovitis in some individuals The frequency with which a supratubercular ridge a shallow bicipital groove or both occurred in the shoulders explored in this study is significant These findings confirm those of Hitchcock and Bechtol However one must admit that other factors such as occupation overuse or even physiologic wear and tear may initiate such a syndrome in the presence of a normal groove for as has been shown the long biceps tendon works at all times at a great mechanical disadvantage

Older Age Group In this group the onset and the course of the illness is similar

to that recorded for the younger age group, except that older individuals are more prone to develop frozen shoulders This is especially true in individuals who are below par physically, or when the lesion is associated with some debilitating disease. It was noted in this investigation that regardless of what other factors are responsible for frozen shoulders, increasing age plays a definite role Once a frozen shoulder is developed it pursues a clinical course similar to that described in older individuals, with frozen shoulders following minor or severe injuries about the shoulder joint

That frozen shoulder is not ushered in always by a bicipital tenosynovitis is illustrated by the following cases

Three women (H B, C R. and V T, aged 47, 53 and 54, respectively) developed frozen shoulders subsequent to fractures of the distal end of the radius and the ulna Following reduction of the fractures the arms were immobilized in plaster casts and supported in slings. Maintenance of shoulder motion was disregarded during the period of immobilization of the fractures Prior to the injuries all these individuals stated that there were no symptoms or signs which were indicative of pathologic disorders in their shoulders All had complete and painless motion From 3 to 6 weeks after the injuries, they became aware of stiffness and a dull ache in the shoulder on the affected side These symptoms progressed steadily When the patients were examined (H B 8 weeks C. R. 11 weeks and V T, 16 weeks respectively) after their injuries all disclosed typical frozen shoulders Another individual T W aged 54, sustained an injury to the dorsum of the right hand which necessitated a skin graft He too, had no symptoms referable to his right shoulder prior to the time this operative procedure was undertaken In order to swing a full thickness pedicle skin graft from the abdomen to the dorsum of the right hand the upper extremity had to be placed in a position of complete adduction and internal rotation This position was maintained by plaster swathes for 4 weeks During this period he was conscious of a constant, deep-seated pain in the right shoulder, the pain being more severe at night At the time the graft was released from the abdomen, it was noted that there existed a *frozen shoulder* Only a few degrees of scapulohumeral motion were demonstrable in the anteroposterior plane

The affected shoulders of three of these patients were explored Varying degrees of inflammation were disclosed in the subacromial bursae Essentially, the changes noted were increased congestion and thickening of the roof and the floor of the bursa one bursal sac was loculated by several firm dense adhesions In all, the musculotendinous cuff and inferior portion of the capsule were adherent to the humeral head Any attempt at internal or external rotation or abduction put these structures on a stretch If the forces of abduction and external rotation were continued, tears in the subscapularis tendon and in the lower subscapularis muscle fibers were plainly discernible

All three bicipital tendon sheaths were thickened, edematous and injected Numerous veil like, red adhesions were demonstrable between the tendon and the tendon sheath and the roof and the floor of the groove The process extended into the joint cavity involving the distal end of the intracapsular portion of the biceps tendon and the adjacent surface of the capsule

Grossly, the findings were that of an inflammatory process involving the capsule the musculotendinous cuff the synovial membrane, the biceps tendon and, to a lesser degree the subacromial bursa. In the light of these observations, it is reasonable to conclude that the involvement of the biceps tendon and its sheath was secondary to a generalized inflammatory reaction affecting all structures in this region However it becomes obvious that the obliteration of the tendon tendon-sheath mechanism may play a major role in retarding recovery therefore, the illness must now pursue a clinical course similar to that described in patients with frozen shoulders which were initiated

by a bicipital tenosynovitis of traumatic or nontraumatic origin

Treatment. From this study it is apparent that bicipital tenosynovitis should be treated conservatively regardless of the causative agents in the early stages Rest to the part and restriction of motion within the painless arcs usually suffice to terminate the syndrome Surgical intervention is justified only in those instances showing a steady progression of the intensity of the illness which fails to respond to conservative measures, also, it is justified in individuals in whom there are repeated recurrences of the symptom complex which results in much discomfort and protracted disability The operation preferred is transplantation of the biceps tendon to the coracoid process.

As the result of this investigation, one is forced to concede that our present-day concept of the management of severe fractures about the humeral head and tears of the

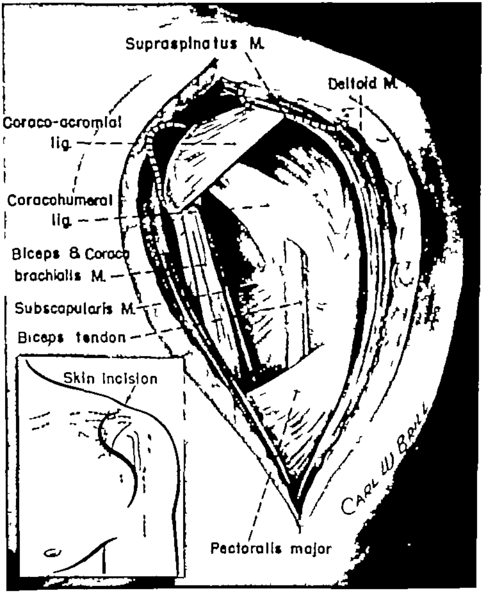

Fig 168 Exposure of anterior aspect of the shoulder by the S-shaped skin incision of Hitchcock and Bechtol as shown in insert. The deeper structures are exposed by developing the deltopectoral cleft and retracting the deltoid muscle laterally and the pectoralis major muscle mesially Approximately 1 centimeter of the medial border of the deltoid muscle together with the cephalic vein are displaced medially with the pectoralis major muscle.

musculotendinous cuff, involving chiefly the supraspinatus tendon requires some re vision Considering the frequency of bicipi tal tenosynovitis following humeral head fractures, one should anticipate this sequela In instances which demand surgical inter vention, the bicipital area should be in vestigated, and, if there is evidence of involvement of the tendon tendon sheath mechanism, the tendon should be trans- planted to the coracoid process as a primary measure This is especially true of the fol lowing types of cases (1) cases with frac ture dislocations of the humeral head in which the biceps tendon has been dislocated from the upper portion of the groove (2) cases of fractures of the greater tuber osity, with retraction of the fragments under

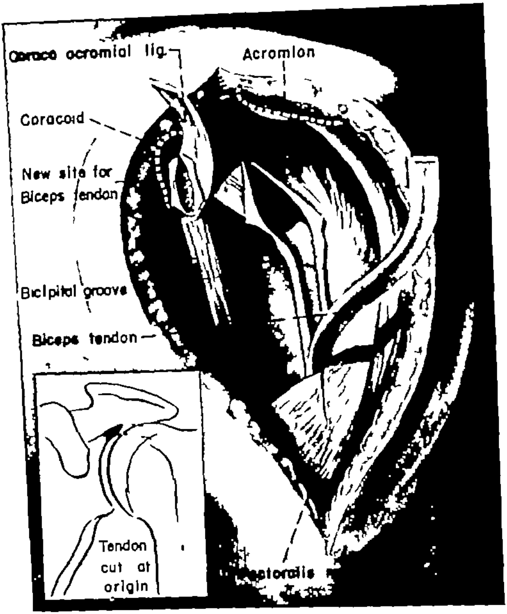

Fig 169 The intertubercular groove is opened by a longitudinal incision through the transverse humeral ligament the incision is extended through the fibers of the coracohumeral ligament in the interval between the subscapularis and the supraspinatus muscles next, the biceps tendon is severed at the superior glenoid brim and withdrawn from the joint cavity The coraco-acromial ligament is divided close to its insertion into the acromion also the tendinous fibers of the insertion of the pectoralis major are divided for 2 to 3 centimeters. A bony trough is cut out of the coracoid process.

the acromion in which the fracture line traverses the bicipital sulcus and (3) cases of depressed fractures of the greater tuberosity in which the biceps tendon is compressed by displaced fragments of bone In 8 individuals who had lesions similar to those just enumerated the biceps tendon was transplanted to the coracoid process in no instance did a bicipital tenosynovitis develop In 6 others in whom the tendon was not transplanted a typical bicipital syndrome developed Two of the 6 terminated in a frozen shoulder This investigation further emphasizes the clinical observation that rupture of the supraspinatus tendon is compatible with good painless shoulder function and that if pain and limitation of motion are present the most likely underlying etiologic factor is a bicipital tenosynovitis

Surgical intervention is also justifiable in individuals with a bicipital syndrome in whom a frozen shoulder appears inevitable.

Operative Technic The anterior portion of the deltoid muscle is exposed through an S-shaped skin incision After splitting the

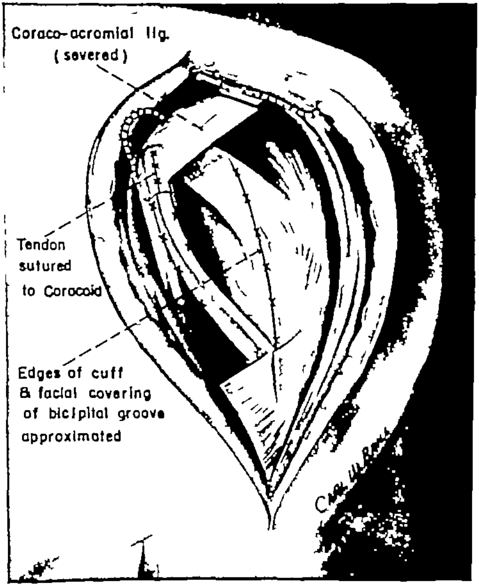

Fig 170 The biceps tendon is sutured in the trough in the coracoid process and to the tendon of the short head of the biceps brachii muscle the incision in the coracohumeral and transverse humeral ligaments is closed by interrupted sutures.

deltoid muscle fibers the musculotendinous cuff and the subacromial bursa are carefully inspected By rotating the humerus inward and outward, the entire tendinous portion of the rotator cuff can be visualized The transverse humeral ligament and the capsule bridging the intertubercular area are then incised longitudinally, thereby exposing the extracapsular portion of the biceps tendon This incision is extended proximally through the outer fibers of the coracohumeral ligament for a distance of 2 inches. Such an exposure provides adequate visibility of the intracapsular portion of the biceps tendon Next, the biceps tendon is severed close to its site of origin from the apex of the glenoid cavity and withdrawn from the joint cavity

A vertical incision ½ inch long is made over the tip of the coracoid process through the fibers of the coracobrachialis and the short head of the biceps brachii muscles which arise from this point The coracoid process is exposed subperiosteally and, with a small gauge a vertical trough is made in its substance The biceps tendon is sutured in the bony trough and covered with periosteum and the tendinous fibers of the coracobrachialis and the short head of the biceps muscles About 2 inches of the proximal end of the biceps tendon is sutured to the combined tendon of the coracobrachialis and the short head of the biceps muscle with medium silk sutures Fine silk sutures are used to approximate the edges of the incised fibrous capsule and the transverse humeral ligament The wound is then closed in the usual manner The arm is not forced through its normal range of movements at the glenohumeral joint

No external fixation is employed other than a sling Pendulum motion is started the next day and is performed a prescribed number of times every hour on the hour by the clock The sling is discarded after 5 days. The range of motion is increased progressively, but it is kept always within the tolerance of the patient. Optimum return of function is gradually restored, the time varies from 3 to 4 months however, the patients are now free of pain

In all instances in which this procedure was carried out the patients were dramatically relieved of their old pain and restoration of motion was initiated promptly This

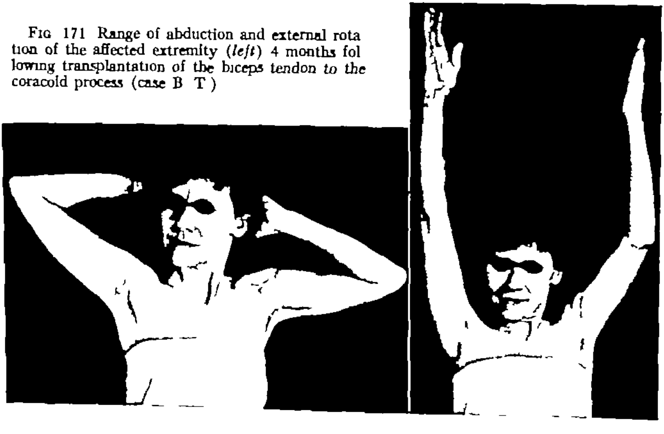

FIG 171 Range of abduction and external rotation of the affected extremity (*left*) 4 months following transplantation of the biceps tendon to the coracoid process (case B T)

was true not only of cases with uncomplicated tenosynovitis, but also of cases with frozen shoulders

CORACO-ACROMIAL LIGAMENT

Frequently this structure acts as a definite mechanical barrier to the humeral head when the extremity is abducted Division of the ligament allows the head to pass beneath the coraco-acromial arch with considerable freedom This procedure is found to be especially useful in frozen shoulders in which the head has risen high in the glenoid cavity and abutts against the coraco-acromial ligament. At this point a review of the anatomy of the coraco-acromial ligament is indicated It is a triangular structure whose apex inserts into the inner side of the acromion while its broad base inserts into the outer border of the coracoid process. Its inner and outer portions are strong its center is weak. In fact in some instances the central area consists of fine areolar tissue transversed by weak fibrous strands. This anatomic arrangement demands that if the ligament is divided it should be severed close to its insertion into the acromion in order to release all its fibers (Fig 13)

CORACOHUMERAL LIGAMENT

As previously stated, the coracohumeral ligament with the arm at the side and rotated internally is in a relaxed and shortened state In frozen shoulders this structure is similarly involved as are all the soft tissue elements comprising the rotator muscles and the musculotendinous cuff It is converted into a strong thickened shortened fibrous band extending from the horizontal limb of the coracoid process to the fibrous capsule as far as both tuberosities In this form the ligament acts as a powerful checkrein to external rotation and abduction. Therefore, it becomes apparent that division of this structure will promote early restoration of glenohumeral motion In all operative procedures on frozen shoulders this ligament has been severed along its line of insertion into the coracoid process

The operative technic described was adopted because of the unsatisfactory results obtained with other procedures Lippmann s method of fixation of the biceps tendon was performed in the first 6 cases of bicipital tenosynovitis, 2 of which exhibited also frozen shoulders In all the convalescence was a protracted one In spite of intensive physical therapy restoration of motion was slow and painful Although these individuals made a good recovery eventually, the average time to obtain this result was 5½ months. This method was discarded, and one similar to that described by Hitchcock and Bechtol was performed on the next 6 cases The results in this series showed no improvement over the previous group Finally the surgical procedure herein described was evolved and has given satisfactory results in a shorter period of time

SUMMARY

1 Bicipital tenosynovitis is not an uncommon lesion causing pain and stiffness in region of the shoulder joint It may be associated with minor or severe injuries about the shoulder or it may have no relation to trauma

2 Because of morphologic changes in the humerus and the scapula and because of the demands made on a prehensile extremity the biceps tendon functions at a great mechanical disadvantage These factors render the tendon vulnerable to repeated trauma during normal joint motion

3 Grossly macroscopic degenerative alterations were noted in the musculotendinous cuff the capsule and the synovialis in the fifth decennium. Microscopic changes were discernible in the third decade These lesions increased in gradient in each successive decade pointing to the parallelism between degenerative lesions and senescence

4 Regardless of the cause no instance of bicipital tenosynovitis under 30 years of age terminated in a frozen shoulder Frozen shoulders were encountered most frequently after 40 years of age

5 Any agent which restricts scapulohu-

meral motion may initiate the processes responsible for frozen shoulders, provided that there are present degenerative changes in the soft tissue elements of the scapulohumeral joint Bicipital tenosynovitis is the most common etiologic factor

6 Essentially, these processes comprise slowing of the circulation venous and lymphatic stasis, accumulation of serofibrinous exudates, and formation of adhesions in and about all the soft tissue structures of the scapulohumeral joint, including the biceps tendon tendon sheath mechanism In the younger age groups these processes do not progress to the degree which result in frozen shoulders, while after 40 years of age, in which degenerative lesions are readily demonstrable, frozen shoulders are not infrequent sequels

7 Adhesions involving the tendon tendon sheath mechanism afford a mechanical barrier to excursion of the humeral head on the biceps tendon only when they bind the tendon to the inner surface of the capsule

8 Bicipital tenosynovitis is a frequent concomitant lesion with fractures of the upper end of the humerus and also associated frequently with lesions of the musculotendinous cuff without fractures

9 Bicipital tenosynovitis associated with supraspinatus tears may be the responsible lesion for the symptoms. Supraspinatus lesions are compatible with painless and complete shoulder motion These observations are not in agreement with Codman, who was of the opinion that supraspinatus lesions (partial or complete) were the most common factors responsible for painful and stiff shoulders

10 An operative procedure is offered for treatment of bicipital tenosynovitis and frozen shoulder

RUPTURE OF THE BICEPS TENDON

Proximal Tendon Ruptures

General Considerations Rupture through a normal tendon rarely occurs A few instances have been recorded, however, in which rupture of the biceps tendon followed violent unguarded exertion in young athletes As a rule, the lesion is encountered in those past middle life and it occurs in tendons exhibiting varying degrees of degeneration As pointed out in the second part of the discussion of degenerative lesions of the shoulder joint, macroscopic manifestations of degeneration in the tendon are common findings in normal shoulders They increase in severity with each subsequent decade and result from aging and attrition Hypertrophic bony alterations in the articular cartilage of the head of the humerus, the tuberosities and the intertubercular groove are partially responsible for such attritional changes as shredding, fraying and, finally partial or complete rupture of the tendon fibers.

Spontaneous rupture is not an infrequent occurrence in shoulders possessing advanced degenerative lesions in the cuff and the head of the humerus In some shoulders with marked degenerative lesions before complete severance of the tendon occurs, the extracapsular portion of the tendon attains a bony attachment on the shaft of the humerus below the lesser tuberosity There fore it is apparent that forceful contraction of the biceps brachii muscle may produce a partial or complete rupture of such degenerative tendons

Meyer pointed out that occupation may play a major role in accentuating the degenerative lesions associated with aging, especially when the arms are used in a position of external rotation and abduction This forces the tendon firmly against the lesser tuberosity favors subluxation of the tendon and produces frictional forces, which cause fraying, shredding and tearing of tendon fibers Excessive fatigue superimposed upon degenerative and attritional changes may result in rupture of the tendon Gilcreest reported that 83 per cent of the ruptures of the tendon are caused by indirect trauma (contraction of the biceps muscle) Direct trauma such as a fall or direct blow

FIG 172 Rupture of biceps tendon In this instance the rupture occurred at the supraglenoid tubercle When the supinated forearm is flexed against resistance the biceps muscle forms a bulge in the lower part of the arm.

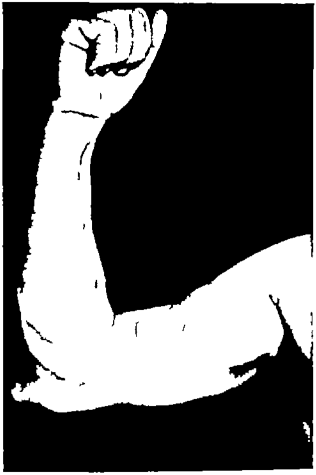

FIG 173 Rupture of biceps muscle at the lower musculotendinous junction When the biceps muscle is contracted the muscle mass is displaced proximally to the upper part of the arm Note the flattened area in the lower part of the arm below the bulge made by the contracted muscle.

to the arm or the shoulder may be the precipitating cause in some cases.

Site of Rupture The site of rupture varies In Gilcreest s series of 73 operative cases 34 disclosed a rupture in the intra capsular portion of the tendon The weakest portion of the tendon is the segment lying in the intertubercular sulcus just distal to its point of exit from the joint cavity Less frequently the rupture may occur at the supraglenoid tuberosity at the musculotendinous junctions or within the muscle mass. In 9 of Gilcreest s 73 operated cases the tendon was avulsed from the supra glenoid tuberosity and in 22 the tear was located at the musculotendinous conjuncture, 20 being at the upper musculotendinous juncture

In most cases there is total rupture of the tendon occasionally there may be partial rupture Meyer reported 2 partial ruptures of the tendon. With complete rupture the tendon may be found curled up at varying distances below the level of the intertubercular sulcus or it may bend upon itself like a ' jackknife in cases of partial rupture the torn fibers may reattach themselves to the bicipital groove (Fig 175)

Clinical Features. These vary and are governed by such factors as the state of the tendon whether it is normal or degenerated the site of the rupture whether the lesion is partial or complete and whether the tear is sudden or gradual If the lesion occurs in a normal tendon or one exhibiting only minimal degenerative lesions there is, as a rule a history of sudden contraction of the biceps muscle against some resistance followed by an audible snap and sharp lancinating pain in the shoulder which radiates to the anterior aspect of the upper arm. On the other hand in a tendon already weakened by degenerative and attritional alterations a rupture may occur without a

specific incidence of onset Usually, these individuals give a history of vague distress, of weakness and of some impairment of function of the shoulder These symptoms often parade under the erroneous diagnoses of arthritis, bursitis, tendinitis, sprains, etc.

The appearance of the upper arm varies according to whether the rupture of the tendon is complete or incomplete, and the site of the lesion. In complete lesions of the tendon the muscle mass will be drawn to a lower level, forming a soft swelling in the lower third of the upper arm when the forearm is extended when the elbow is flexed the mass becomes firmer but does not reach the hardness of the biceps muscle on the normal side The interval between the deltoid and the biceps muscle is increased (Fig 172) A complete rupture at the lower musculotendinous joint exhibits a muscle mass drawn upward in the upper third of the arm while the lower third appears flattened (Fig 173)

It is obvious that in partial ruptures the size and the position of the swelling will depend upon the extent of the tear and the distance the muscle belly is permitted to be drawn away from the site of rupture Rupture of the muscle belly allows the formation of a hiatus between the two ends its size being governed by the severity of the tear In complete tears a wide gap is demonstrable when the forearm is flexed against resistance In minor incomplete tears only a small sulcus is demonstrable

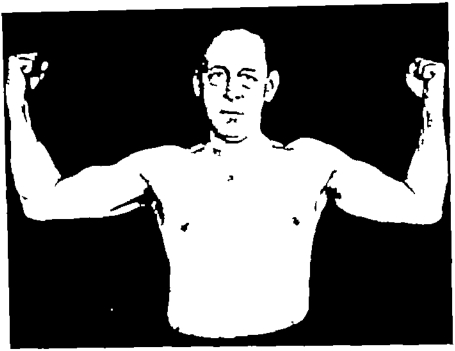

FIG 174 Rupture of the biceps causing no symptoms other than minimal weakness of the arm In view of the absence of pain and little or no impairment of function, surgical intervention is not justifiable.

No hematoma or ecchymosis results in high, acute ruptures if the lesion occurs through an avascular portion of the tendon whereas in lesions through the belly of the muscle or at the musculotendinous junctions a large hematoma and discoloration of the anterior and the inner aspects of the upper arm may occur Also in recent lesions pressure over the bicipital groove and over the muscle swelling elicits varying intensities of tenderness and pain which gradually subside until only some soreness remains No significant tenderness is demonstrable in

old cases or in those resulting from degeneration of attritional changes

The tests of Yergason, of Ludington and of Hueter may be of some diagnostic value

Yergason's Test When the elbow is flexed 90° and the forearm is pronated active supination of the forearm against resistance produces pain in the bicipital groove indicating lesions of the biceps tendon or its sheath or both This is not a very dependable test

Ludington's Test The patient places both hands with fingers interlocked and palms downward on the top of the head, with the weight of the extremities supported by the interlocked fingers In this position the patient is made to contract and relax the biceps muscles Active contraction can be palpated readily on the normal side but not on the affected side indicating a rupture or elongation of the tendon

Hueter's Test When the biceps muscle is relaxed flexion of the forearm is more forceful in pronation than in supination

Impairment of function depends in a large measure on the location and the extent of the lesion and the initiating causative agent In acute traumatic ruptures of the tendon or the belly of the muscle severe impairment of function may result pronounced weakness and pain may persist after the acute painful symptoms have subsided On the other hand this lesion may cause insignificant disability in some individuals (Fig 174) Lesions with a gradual onset in elderly individuals and due to degenerative and attritional lesions seldom produce severe impairment of function However some stiffness and soreness in the shoulder may be present

Treatment. Surgical repair is not always indicated in rupture of the biceps tendon. This is particularly true of latent lesions in elderly individuals whose impairment of function is not great and whose functional demands are diminishing Conservative treatment of either partial or complete lesions is of doubtful value If weakness and pronounced impairment of function exist surgical intervention is indicated since it assures the patient of restoration of function in a relatively short period of time

The choice of procedure is governed by the type and the location of the lesion If the rupture occurs in the intracapsular portion of the tendon, transplantation of the distal end of the tendon to the coracoid process gives excellent result, or, as Gilcreest recommended the tendon may be sutured to the short head of the biceps to the intertubercular groove to the pectoralis major or to the deltoid muscle

When the length of the tendon permits the author prefers to anchor it to the coracoid process as shown in Figure 170 if the tendon is short it is reattached to the intertubercular sulcus

Recent ruptures in the belly of the muscle or at the musculotendinous junctions are best repaired by deep interrupted mattress sutures of cotton or silk If the suture line appears to be weak it may be reinforced by a fascial transplant Old ruptures sometimes require excision of considerable scar tissue. The suture lines in these cases should be routinely reinforced by a fascial transplant. End to-end suture of the biceps tendon is done by the author only if the ends are healthy and readily approximated with minimum tension

Postoperative Management. The arm is immobilized in a plaster swathe for 3 weeks (Fig 198) Physical therapy is then begun to improve shoulder and elbow motion. Active flexion of the elbow is not permitted for 6 weeks no forceful contractions are permitted before 10 weeks

Traumatic Dislocation of the Tendon of the Long Head of the Biceps Brachii Muscle

General Considerations. Varying degrees of displacement of the biceps tendon from the intertubercular groove was demonstrated in the specimens studied in the investigation on degenerative lesions of the shoulder joint As first pointed out by Meyer the subluxation or dislocation of the

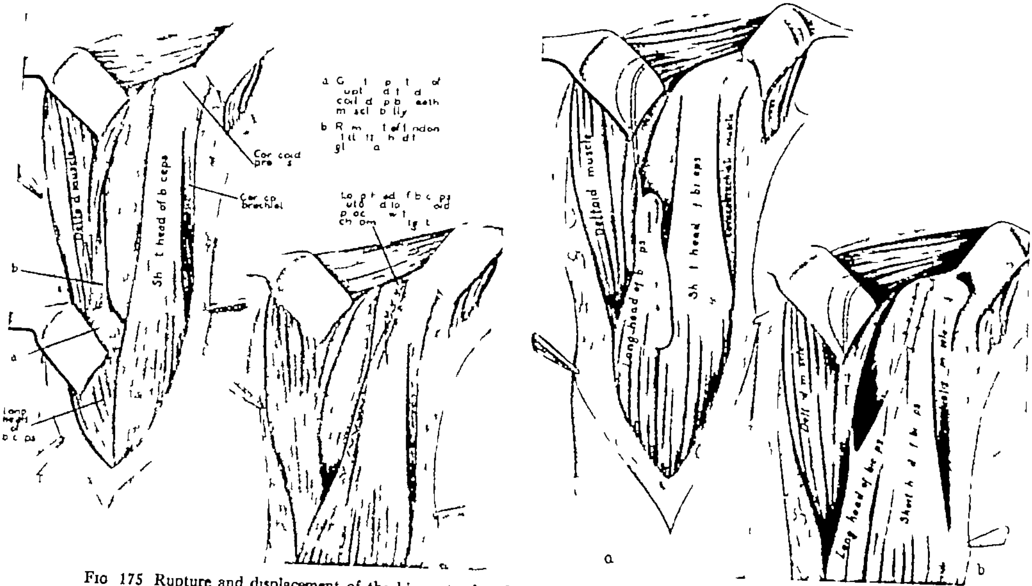

Fig 175 Rupture and displacement of the biceps tendon Rupture has occurred at the lip of the glenoid. (Gilcreest, Surg, Gynec & Obst 58 326)

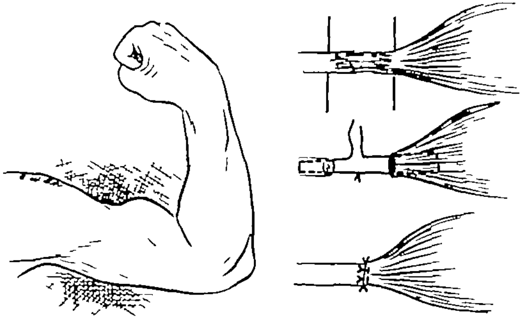

FIG 176 Technic of repair of rupture of the biceps tendon at the level of the upper musculotendinous juncture.

tendon was produced by gradual tearing away and elongation of the fibrous expansion of the insertion of the pectoralis major muscle and of the upper border of the subscapularis muscle from the anterior lip of the intertubercular sulcus Hitchcock and Bechtol further pointed out that displacement of the tendon may be enhanced by the presence of a supratubercular ridge in the intertubercular sulcus

All these observations have been confirmed in the study on degenerative lesions of the shoulder in Chaper 3 However one is forced to agree with Abbott and Saunders that acute traumatic dislocations of the biceps tendon differ from those observed in shoulder joints of elderly individuals exhibiting advanced degenerative abnormalities In traumatic lesions the presence of a supratubercular ridge facilitates the displacement of the tendon Strenuous efforts with the arm in abduction and external rotation are responsible for the displacement, as a rule. In this position the tendon is forced against the lesser tuberosity In the study on bicipital tenosynovitis 3 patients were encountered who could subluxate voluntarily the biceps tendon by abducting and rotating the arm externally in each instance a snap was heard and felt when the maneuver was executed The resulting tenosynovitis associated with acute and chronic dislocation of the tendon plays a major role in the symptomatology present

Clinical Features. Generally the syndrome is initiated by forceful abduction and external rotation movements of the arm. Occasionally displacement occurs repeatedly without a traumatic incident In the acute traumatic cases the onset is followed by severe pain in the anterolateral aspect of the shoulder which is often projected to the anterior aspect of the upper arm There is loss of power Motion is restricted and painful particularly in movements of abduction and external rotation and of forward flexion and abduction. A snap which is felt and often heard can be produced by having the patient bring the arm down from an elevated position in the coronal plane with the arm rotated externally The snap is heard as the arm passes below the horizontal at which time the biceps tendon slips mesially over the lesser tuberosity Once displacement has occurred recurrent dislocation of the tendon is the rule In the

chronic forms, repeated displacement produces inflammatory changes in the tendon tendon-sheath mechanism, consistent with the tenosynovitis, causing pain and stiff shoulders

Treatment Surgical intervention is the proper treatment The region is exposed adequately by a deltopectoral incision Reconstruction of the fibrous covering of the intertubercular sulcus is not practicable Such a procedure, if feasible, predisposes to formation of adhesions between the tendon sheath and the bicipital groove The method of choice is severing the tendon at the superior glenoid brim and suturing it to the coracoid process (Fig 170) As an alternative, the end of the tendon can be sutured to the bicipital groove

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6

Calcareous Tendinitis of the Musculotendinous Cuff

It is common knowledge that calcareous tendinitis is the most frequent cause of painful shoulders Codman gave no actual statistics on the frequency of this lesion but was of the opinion that it was more common than any other affection involving the subacromial region The author's statistics on 300 consecutive shoulder lesions disclosed calcareous tendinitis to be the etiologic factor in 43 per cent of the cases

The term calcareous tendinitis is chosen because it more adequately conveys the basic pathologic process responsible for this syndrome. "Subdeltoid," or "subacromial bursitis with calcification "bursitis calculoso and calcified deposits in the supraspinatous tendon portray a false pathologic concept of the entity As will be shown subsequently the subacromial bursa is rarely if ever primarily involved Reactionary changes in this structure always *are secondary to an irritating focus in the* adjacent tissues. Calcareous material may be observed *in any portion of the musculotendinous cuff* Thus the designation "*calcification in the supraspinatus tendon" may* be a misnomer

Calcareous tendinitis has been described in relation to practically all tendons of the body Next in frequency to the fibrotendinous cuff, it has been observed in the region of the greater trochanter and radiohumeral joint The author also has encountered it in the tendo achillis and in the flexor tendon of the fingers Cooper recorded the lesion in the metacarpophalangeal region

SITE AND SEX

The lesion may occur in one or multiple areas of the cuff In over 50 per cent of the *affected shoulders it is observed as a single* lesion involving the supraspinatus region of *the cuff and encountered only rarely in the* subscapularis tendon. Males are affected more frequently than females *The right* shoulder is involved two times as often as the left One half of the affected individuals reveal calcareous deposits in both shoulders

AGE

Generally, calcareous tendinitis occurs in the fourth and the fifth decades but is ob*served occasionally in the latter part of the* third decade Rarely is it encountered after the sixth. *The average age is 45 years*

OCCUPATION

Whereas ruptures of the cuff do occur in individuals doing laborious work, calcareous tendinitis is primarily a disease of persons employed in occupations, often sedentary, involving the use of the arms in slight abduction for hours at a time Clerks, typists, stenographers and surgeons may be victims As previously noted, the musculotendinous cuff is not mechanically suited to meet such abnormal stresses and strains, and if exposed to forces of this nature, attrition alterations ensue which accentuate the normal early degenerative changes that take place in this region during normal joint function

TRAUMA

Excessive use of the arm which inflicts undue strain on the rotator cuff may be considered a form of trauma and the accumulative effect may be responsible for advanced degenerative changes in the involved tissue Calcification in the tendon fibers is evidence of nature s frustrated attempt to repair It is reasonable to assume however that sudden trauma in the early and middle age groups may be responsible for the tearing and the shredding of tendon fibers, followed by hemorrhage into the substance of the tendon, faulty repair and calcification

A considerable interval must elapse between the initial trauma and radiographic evidence of calcification in the traumatized tendon It is never demonstrable by radiographic examination made immediately after the injury One case aged 32 was observed for 9 months before calcareous material was seen by radiographic examination Excessive use in general and particularly occupations demanding overuse of the arm in abducted positions are predisposing if not etiologic factors Sudden trauma may accentuate a subacute clinical stage of the syndrome or precipitate an acute syndrome but it is not responsible for the calcareous tendinitis It is generally known that calcified deposits in a tendon do not always produce symptoms Many are quiescent and only accidentally discovered by the radiologist Symptoms arise only when the sensitive peritendinous tissues are involved secondarily One is led to conclude that the

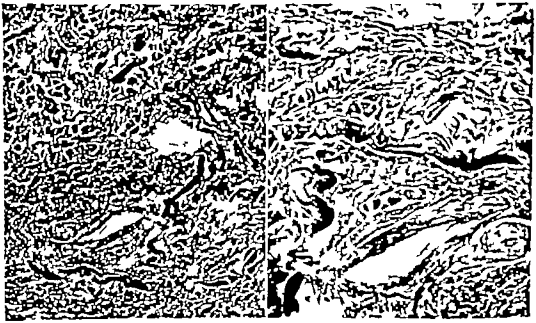

Fig 177 (*Left*) Calcareous tendinitis in supraspinatus tendon responsible for a subacute syndrome Advanced degeneration of tendon fibers is manifested by fragmentation of fibers and the presence of debris. Observe the presence of calcium deposits and round-cell infiltration (× 75) (*Right*) The same section shown at left. (× 150)

lesion precedes any sudden trauma which is immediately followed by the clinical features characteristic of this entity

INFECTION AND CONSTITUTIONAL DISEASES

Infection as a local or distant focus never has been proved to be an etiologic factor Cultures and smears of the calcareous material never have disclosed a responsible organism. Associated distant foci of infection apparently play no part in the course of the disease. Patients with proved foci of infection (poor teeth infected sinuses, etc) respond to therapy regardless of whether the focus was treated or not

No relationship appears, therefore between general disease and calcareous tendinitis The only common denominator in persons affected with the latter is the factor of overuse of the arm in slightly abducted positions

PATHOGENESIS

Many concepts have been formulated relative to the etiology and the mechanism of developing amorphous calcium deposits in tendons As yet the problem remains obscure However, there are certain features on which there is more or less general agreement *Calcareous deposits are common findings in areas of necrosis of degenerated tissues* It has been proved conclusively that degenerative changes occur early in the musculotendinous cuff because this structure is not mechanically and anatomically adequate to meet the demands of a prehensile extremity The point of greatest strain is in the region of the supraspinatus tendon, hence, degenerative lesions are encountered more frequently in this area than elsewhere in the cuff Calcareous deposits in this region are found just proximal to the insertion of the conjoined tendon Codman designated this area as the 'critical zone'—an area which sustains the maximum degree of strains and discloses the most severe degenerative changes It is also the area through which primary transverse ruptures of the cuff occur most often

Generally it is believed that the process begins with degeneration of the central tendon fibers in the "critical zone" This observation is substantiated by the findings in

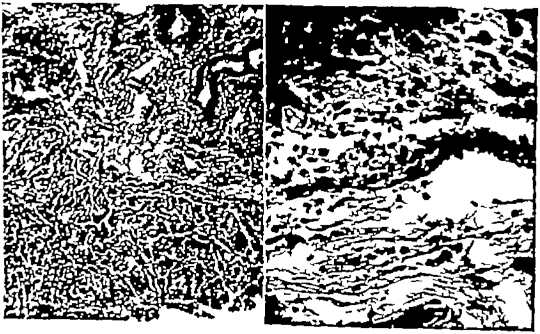

FIG 178. (*Left*) Calcareous tendinitis in supraspinatus tendon causing an acute syndrome. Observe degeneration of tendon fibers, calcium deposits, large blood vessels and infiltration of the tissue by leukocytes and round cells. (× 67) (*Right*) A section of the area depicted at left. (× 267)

autopsy specimens of small degenerated areas within the substance of the tendon having no communication with the joint cavity or the subacromial bursa Small degenerated necrosed bits of tendon fibers were often discernible in these areas Codman believed that the calcareous deposits found in the living are nature's attempt to heal these lesions

Considerable controversy still exists relative to the actual mechanism of calcium deposition in degenerated tissue Howland and Wells have offered a plausible theory which is applicable to lesions observed in the musculotendinous cuff It may be summarized as follows Calcium and inorganic phosphorus are held in solution in the blood serum in much higher concentration than would be possible in water because of high carbon dioxide tension and colloids in blood serum Furthermore a high carbon dioxide tension is maintained by cellular activity hence no precipitation of salts occurs from intercellular fluids. However degenerated or dead tissue lowers the carbon dioxide tension (or produces a relative state of alkalinity), thus favoring precipitation of calcium carbonate or calcium phosphate, or both, in a molecular combination This is a local physiochemical process. Patients having calcareous tendinitis but no other disease have normal blood calcium levels.

PATHOLOGIC ALTERATIONS IN THE SUBACROMIAL BURSA AND MUSCULOTENDINOUS CUFF

The character of the pathologic changes in the subacromial bursa and affected region of the cuff depends upon the size, the location and the consistency of the calcareous material and the severity of the inflammatory reaction around it. As previously stated calcareous deposits form within the substance of the tendon. When they are discrete localized lesions, not irritating the floor of the bursa, there may be no symptoms present They are more or less quiescent and may remain so for many years. Frequently such lesions are discovered accidentally by the radiologist

Fig 179 (*Left*) Section of calcareous tendinitis in subscapularis tendon causing an acute syndrome. Note numerous areas of calcium deposits pronounced infiltration of round cells and leukocytes along with advanced degeneration of tendon fibers. (× 67) (*Right*) Subacromial bursa in case depicted at left. Observe increased vascularity pronounced infiltration of leukocytes and round cells, and edema and thickening of the bursal wall (× 134)

At this stage, no changes are discernible in the bursa Usually the deposits enlarge gradually until they reach the floor of the bursa In this position they may cause pain on abduction and elevation or rotation of the arm Symptoms are the result of mechanical impingement of the lesion against the edge of the coraco-acromial arch during the above arcs of motion Frictional trauma of this nature is responsible for secondary changes in the floor of the bursa. Now the deposit appears as a well-defined mild swelling with a white center, not under tension The floor of the bursa may be thickened and covered with numerous villi of varying sizes

Incision of the tumefaction discloses a whitish, gritty material incorporated within the tendon fibers. Removal can be achieved only by curettage or excision of the entire area If curetted degenerated tendon fibers are noted in the gritty material. Often a fair sized cavity remains, the borders of which are comprised of shredded, degenerated stubs of tendon fibers Lesions just described do not ordinarily give rise to acute symptoms. Clinically, they are considered responsible for mild symptoms only Continued frictional trauma or sudden strains may accentuate the intensity of the symptoms giving rise to a subacute or an acute syndrome, depending upon the intensity of the clinical features

Lesions responsible for the subacute phase lie directly under the bursal floor, which is stretched tightly over the calcareous mound The swelling has a whitish or yellow center surrounded by a circular bluish zone of congested synovial membrane In cases of long standing or repeated aggravation, the floor of the bursa may be thickened and studded with fine synovial villi Adhesions within the bursa are not infrequent findings in this stage

The size of the calcareous mass varies from a few millimeters to 5 or 6 cm in length the average size encountered is about 1½ to 2 cm Upon incision of the top of the mound there escapes a whitish or yellow material which has the consistency of tooth paste Occasionally, gritty material is found in the contents In long standing cases the deposit is incorporated in the tendon fibers and does not flow out of a distinct cavity in the substance of the tendon but must be evacuated with a curette Strands of degenerated tendon fibers are discernible in the calcareous material

During the acute stage the pathologic changes are similar to but of greater intensity than those in the subacute stage If the floor of the bursa has ruptured, varying amounts of a milky fluid, composed of calcareous material and serum, are encountered upon opening the bursa If the floor is intact, serous fluid escapes from the bursa, and the bursal floor may be covered with a film of fibrin

The deposit has a whitish center and is surrounded by a deep-red or violet congested circular zone, the synovial floor of the bursa is stretched tightly over the swelling, which appears to be under great tension If the top of the tumefaction is nicked with a scalpel a milky fluid escapes There appears to be a parallelism between the acuteness of the symptoms and the consistency of the calcareous material

Symptoms in the acute stage are the result of irritation and stretching of the sensitive floor of the bursa. When tension is released the symptoms subside.

Clinical Features

Pain, muscle spasm, restriction of motion, and muscle atrophy are the cardinal features of calcareous tendinitis These symptoms differ greatly in intensity and severity, permitting one to recognize, clinically three distinct variations of the same syndrome the chronic the subacute and the acute syndrome But such a clinical classification must not be adhered to rigidly, since many cases are borderline in character Others present all three stages at different times

Subacute Syndrome

Most patients with calcareous tendinitis

disclose more or less subacute clinical manifestations As a rule, the onset is insidious, the patient first feeling a sudden twinge of pain or a catch in the shoulder during certain motions particularly on abduction and internal rotation

Pain results from impingement of the sensitive irritated area in the musculotendinous cuff against the acromion or coraco-acromial ligament After it has passed under these structures, the pain disappears This explains why many patients find relief in the early stages when they sleep with the hand behind the head As the pain becomes more severe the patient instinctively avoids motions which produce pain and uses the arm only within the painless arcs In mild cases the syndrome may remain static for many months and then it may disappear On the other hand the pain may increase in intensity and even become excruciating at the level of impingement Pain projected to the insertion of the deltoid is a constant observation In severe cases there may be pain referred posteriorly to the inferior angle of the scapula and up the neck to the suboccipital region

Occasionally in the severer forms it radiates to the back of the forearm and to the fingers particularly to the thumb and the index finger The hand may be puffy and the fingers swollen and painful Generally it is more severe at night the patient has great difficulty in finding a comfortable position for the arm He is unable to lie on the affected side Excruciating tenderness usually can be elicited by pressure over the inflamed bursa also pressure over the insertion of the deltoid produces pain in most instances At times a small tender mass which rotates with the humerus can be palpated over the greater tuberosity

In the early stage spasm of the rotator muscles is not a prominent feature being intermittent or absent however with progression in severity of the lesion muscle spasm becomes pronounced and constant The glenohumeral motion is at first markedly restricted and finally obliterated completely Abduction and elevation are now barely possible to the horizontal plane and take place entirely in the scapulothoracic joint, normal scapulohumeral rhythm is lost. Muscle atrophy of the spinati and the deltoid muscles is also an outstanding feature The patient now presents a typical clinical picture of frozen shoulder

It is interesting to note that as the amount of restriction of motion increases, the pain decreases Many cases with little or no glenohumeral motion are practically free of pain

It is apparent that calcareous deposits like bicipital tenosynovitis, may initiate inflammatory changes in the rotator cuff which terminate in frozen shoulder As a rule this process never is permanent. With absorption of the calcareous deposits and healing of the defect in the floor of the subacromial bursa the entire process is reversed adhesions are stretched and absorbed and motion returns.

Fortunately most subacute cases do not run such a violent course As a rule the course is more clement and complete recovery can be anticipated in a relatively short period of time, if the case is treated adequately Some patients have comparatively little pain spasm and restriction of motion are the predominent features from the very onset of the syndrome On the other hand while other patients disclose very little spasm and limitation of motion, the pain may be intense and constant

Acute Syndrome

Acute syndromes run a relatively short fulminating course Generally there is a sudden onset with no previous clinical evidence of any pathologic disorder in the cuff At times the attack is precipitated by overuse of the arm or by trauma or it appears during the course of a subacute or chronic phase The characteristic features are sudden intense pain on any attempts at motion, with localized tenderness and severe spasm of the rotator muscles.

Agonizing pain may appear suddenly dur

ing the night The slightest motion accentuates the pain, which is projected to the deltoid insertion and even to the fingers The usual history is one of sleepless nights, agonizing pain and failure to obtain relief from the usual sedatives In untreated cases, such symptoms may persist for a week or two and then they subside Spasm becomes less severe, and restoration of motion is achieved gradually In some cases, varying degrees of spasm and restriction of motion in the glenohumeral joint may persist for many months following the acute episode Although the interval of time before complete restoration of motion is unpredictable full recovery is a certainty

The sudden onset is the result of an acute inflammatory process involving the floor of the bursa. At this stage the calcareous mass is under great tension it is surrounded by a red, congested zone of synovial tissue Frictional trauma accentuates the pain and produces spasm of the rotators and fixation of the glenohumeral joint Fibrin and a serous exudate pour into the bursa. Should the floor rupture, a milky fluid escapes into the bursa. Thereupon pain subsides, as all tension is relieved Nature readily absorbs the calcified material evacuated into the bursa. If there is complete absorption of the calcareous material, healing ensues and no recurrence is to be anticipated However, if some calcified material remains there is always the possibility of recurrent attacks of an acute syndrome or the lesion may pursue a subacute or chronic course

Chronic Syndrome

Symptoms are very mild in these cases The only complaint may be a sudden catch or slight twinge of pain on internal rotation or elevation of the arm There is no muscle spasm or restriction of motion Pain is the result of mechanical impingement of the calcareous mass against the acromion or the falciform edge of the coraco-acromial ligament during the above-mentioned motions Such a syndrome may persist for years without much apparent disability

Fig 180 Dense, discrete, calcareous deposit, giving rise to no symptoms except an occasional twinge of pain when the arm is abducted.

However at any time (especially if the factor of trauma or excessive use is added) the lesion may pursue a subacute or acute course

RADIOGRAPHIC CHARACTERISTICS

Calcareous deposits range in length from a few millimeters to 5 or 6 centimeters. Although their configuration is considerably variable at first the mass is usually in the long axis of the cuff fibers Later with rupture of the floor of the subacromial bursa and dispersal of the calcium particles an irregular crescent or globular mass may be discernible Generally, in long standing cases in either the chronic or the subacute stage, the deposits are more or less discrete and homogeneous The density may be uniform throughout the entire mass or it may be spotty because of small areas of varying

density scattered throughout the calcareous deposit (Fig 180) In the acute stage the mass is less dense and more spotty It may be amorphous and fluffy in character (Fig 181)

Roentgenographic visualization and precise localization of the deposits may at times prove to be rather difficult Routinely, these *films should be taken in different positions*—in external rotation in internal rotation and at the midposition (Fig 182) In addition Bosworth advocates routine fluoroscopic examination and the taking of spot films The value of such a procedure in some areas is obvious but as a routine measure it is superfluous

Treatment

Treatment in all phases of calcareous tendinitis should be tempered by the knowledge of the following clinical observations

1 The disease is self limiting

2 *All patients, sooner or later, make a* complete recovery, with no residual complications

3 Nature produces relief of symptoms by rupturing the calcareous deposit and allowing it to escape into the bursa where it is absorbed rapidly, or by gradual absorption of the deposit in situ

4 *Complete removal or absorption of the* calcareous material results in a permanent cure Incomplete removal may predispose the patient to recurrences.

5 Recovery is the rule—regardless of the method of treatment, in spite of some treatment and without treatment

Acute Syndrome

During the acute phase pain can be relieved either by aiding nature in evacuating the deposit into the bursa where it will become absorbed or by reducing the inflammatory process in the floor of the bursa

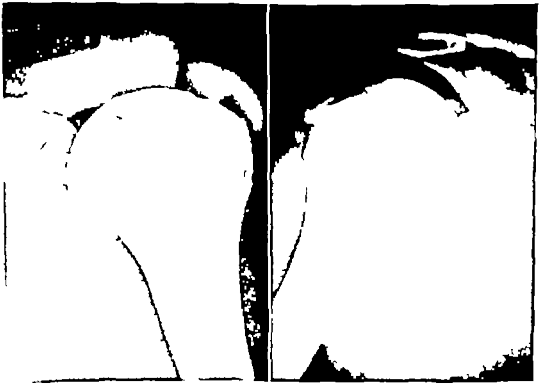

Fig 181 (*Left*) Calcareous deposit in the supraspinatus tendon producing a subacute syndrome Note the irregular small areas of varying density scattered throughout the mass. (*Right*) Small calcareous deposit in supraspinatus tendon producing an acute syndrome Observe the amorphous nature of the mass also note that it has ruptured into the bursa. At operation a white milky serous fluid was found in the subacromial bursa.

Rupture of the deposit can be achieved by one of several methods, such as (1) surgical removal, (2) aspiration and needling, and (3) irrigation of the bursa and manipulation. The intensity of the inflammatory process is best reduced by radiotherapy.

Surgical Removal of the Calcareous Deposit

Although operative intervention may appear to be radical, relief from pain is prompt and certain. The restoration to normalcy is more rapid than in the other two methods indicated above, and nonrecurrence is assured. These advantageous features should be offered to the patient if counterindications to surgery do not exist.

An anterior deltoid splitting incision is simple and provides adequate exposure of the subacromial bursa. The patient is placed on the table in a sitting position with a sand bag under the affected shoulder and another under the corresponding hip. By drawing the patient close to the edge of the table the elbow may be dropped below table level, thereby making the tuberosity more prominent. The hand and the forearm on the affected side are draped so that the arm may be maneuvered freely during the operation.

The skin incision begins immediately below *the acromioclavicular joint and extends* distally on the anterior aspect of the arm for from 2½ to 3 inches. The incision is deepened through the full thickness of the anterior portion of the deltoid by blunt dissection, exposing the roof of the bursa. While the forearm is held vertical to the table, the roof of the bursa is incised, the opening being directly over the bicipital groove. All regions of the bursa can be visualized readily merely by rotating the arm. No difficulty is encountered in locating the calcareous deposit if it is beneath the floor of the bursa in the supraspinatus region of the cuff.

Visualization of the mass may be slightly more difficult if it lies in the subscapularis region or in the extreme end of the infraspinatus or in the teres minor regions. The

Fig. 182 (*Left*) Calcareous deposit in the subscapularis tendon. Observe its relation to the glenoid brim with the arm in internal rotation. (*Right*) Same shoulder with the arm in external rotation. Observe how the position and configuration of the mass has altered as compared to that shown at left.

tumefaction is incised parallel with the cuff fibers and its contents are evacuated with a curette Occasionally, the necrotic walls of the remaining cavity are excised by elliptical incisions parallel with the axis of the tendon fibers The cavity is irrigated thoroughly with normal saline solution If the defect is extensive, it is closed by side to side sutures

A thorough search for the presence of any other deposits should be made and any suspicious areas should be nicked with the

FIG 183 (*Top left*) Calcareous deposit producing an acute fulminating syndrome treated by aspiration and needling (*Top right*) Roentgenogram taken the day after aspiration and needling of calcareous mass depicted at left. Observe that not all calcified material was removed (*Bottom*) Roentgenogram of the shoulder depicted above 4 weeks later Note the complete absorption of calcareous material The patient achieved complete restoration of function.

point of a scalpel to determine the existence of hidden calcareous masses Multiple punctures of the cuff adjacent to the lesion ensure an active hyperemia which favors absorption of any remaining calcareous material To facilitate free excursion of the humeral head under the coraco-acromial arch, the coraco-acromial ligament is divided routinely at its insertion into the medial edge of the acromion, and as much of the bursal sac as is accessible is removed

For the first 24 hours following operation the arm is suspended to an overhead frame with lateral traction On the second day gravity free pendulum exercises are started on a schedule of every three hours for from 3 to 5 minutes. The range of motion is maintained at all times within the patient s tolerance of pain As the acute symptoms subside, exercises are done every hour, and wall-crawling and pulley exercises are added

Physical therapy should supplement this regime Radiant heat and gentle massage to the shoulder girdle and the upper arm add to the comfort of the patient. In most instances full restoration of painless motion is attained in 3 weeks although some few cases (complicated with pronounced fixation of the glenohumeral joint prior to operation) may require from 6 to 8 weeks It is interesting to note that the more acute the syndrome prior to operation the sooner it will recover This observation of course is true of all therapeutic measures employed

Aspiration and Needling

If surgery is contraindicated or refused aspiration and needling are advocated. Although in many instances relief from pain is as dramatic as when surgical intervention is employed it is a more-or less blind procedure If more than one deposit is present one is certain to fail to rupture and evacuate all of them.

The patient assumes the same position on the table as that described for open operation After the point of maximum tenderness is located and marked, the arm is prepared surgically and draped as meticulously as when an open procedure is to be done With a hypodermic needle containing a 1 per cent solution of procaine a small wheal is raised in the skin over the designated point of maximum tenderness A larger-gauge needle is used to infiltrate the subcutaneous tissue, the muscle and the roof of the bursa Anesthesia of the area having been attained, an 18-gauge needle is then directed toward the calcareous mass, which in some instances is distinctly palpable As the needle penetrates the calcified area a definite sensation of grating is felt Upon withdrawal of the plunger, some fine flaky, calcareous material will be aspirated into the syringe

Barbotage is continued at various levels in the calcareous mass until all accessible calcified particles are removed This is indicated by the return of clear fluid into the syringe A 1 per cent solution of procaine is used throughout the procedure (Fig 184)

To assure absorption of any remaining particles the entire area is multiple-punctured with a large straight skin needle The adjacent areas, as well as the site of the calcareous mass, are punctured thoroughly An active hyperemia is produced, which dissolves and absorbs the calcareous material left in situ Puncturing also allows some of the particles to escape into the bursal sac where they are absorbed readily (Fig 183)

After treatment

For the first 24 or 48 hours following aspiration and needling the patient should be kept under sedation Hot packs should be applied to the shoulder If possible the arm should be suspended from an overhead frame and lateral traction should be applied The patient must be encouraged to move the arm several times a day through a normal range of motion.

When the patient arises from bed gravity free pendulum exercises are begun with wall-crawling and pulley exercises added

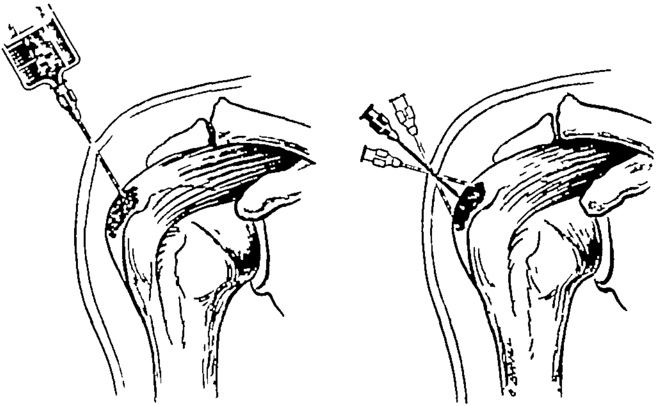

FIG 184 Aspiration and needling of the calcareous deposit in the supraspinatus tendon.

later Motion should be executed within a painless arc. As sensitivity diminishes, the arc of motion is increased Radiant heat and gentle massage may be added to this regimen

Occasionally one fails to aspirate calcareous material In such instances, multiple-puncture of the area as described above is performed Rupture of the floor of the bursa will relieve tension and allow calcified particles to disperse into the bursa where they will be absorbed Absorption of the calcareous mass is still further enhanced by the hyperemia which follows the puncturing Although this procedure is not as efficacious as aspiration and needling it will alleviate the acute symptoms in most instances

IRRIGATION

Patterson and Darrach described a technic of irrigation of the subacromial bursa as a result of which they recorded complete relief of symptoms in 57 of 63 cases with an average economic disability of 4.8 days Essentially the method comprises continuous irrigation of the bursa with two 18-gauge needles Normal saline is forced out of one needle and through the other Washing of the bursa continues until the fluid flowing out of the second needle is clear (usually from 30 to 60 cc of saline solution is used) Following irrigation the patient is encouraged to move the arm in all directions Occasionally gentle manipulation is employed to break up adhesions in long standing cases After treatment is essentially the same as that following aspiration and needling

MANIPULATION

Some workers occasionally manipulate the shoulder during the acute stage. The author does not advocate this method except when the purpose of the manipulation is rupture of the deposit. Once the floor of the bursa overlying the calcareous mass is ruptured and the mass dispersed into the bursa relief of symptoms is assured and absorption of the calcium follows

Roentgen Ray Therapy

There is general agreement that roentgen radiation is a valuable method of treatment during the acute phase of some cases Some workers claim unusual dramatic cures Isidore Lattman recorded that patients were relieved of acute symptoms and restored to normalcy more rapidly by this method than by any other relief being obtained in 15 of 20 cases within from 24 to 48 hours However Sandstrom reported that of 75 cases more than half were treated for from 2 to 5 weeks a quarter for from 2 to 4 months and a few for over a year

The author has seen some quick dramatic cures following irradiation therapy In some instances however pain was greatly accentuated after treatment, while recovery was slow in others Several patients had recurrences. Therefore roentgen ray therapy is advocated only when operative intervention and aspiration and needling are contraindicated or refused. It is believed that irradiation produces relief of symptoms by decreasing the intensity of the inflammatory process thereby reducing the tension beneath the floor of the bursa.

SUBACUTE AND CHRONIC SYNDROME

Calcareous deposits in the subacute and chronic phases vary greatly in texture ranging from a homogeneous tooth paste consistency to discrete circumscribed dense masses (Figs 180 and 181 *left*) In more acute cases the masses tend to assume an amorphous character In the absence of pronounced inflammatory changes the symptoms are produced by mechanical impingement of the calcareous deposit against the coraco-acromial ligament or acromion. As previously noted both the subacute and the chronic phases may be transformed into an acute syndrome gradually or suddenly and with or without provocation.

Management is similar to that described for the acute stage Surgical removal and needling assure the patient a more rapid and more nearly complete recovery Inasmuch as the lesions may be well circumscribed and the symptoms not too pronounced aspiration and needling or needling alone may produce the desired results Whatever the choice of treatment it should be supplemented by such intensive physical therapy as gravity free pendulum exercises wall crawling and pulley exercises

This is particularly true in long standing cases or in cases with repeated attacks of acute exacerbations of pain in which there may be varying degrees of restriction in the glenohumeral joint with contractures and shortening of the internal rotator and adductor muscles

Roentgen-ray therapy is believed by some workers to give satisfactory results in subacute cases However it is of doubtful value in the chronic cases As in the acute form, pain may be intensified after the first or second dose making sedation and analgesic medication necessary Unless the pain is too intense the patient is encouraged and urged to follow the prescribed regimen of exercises previously described to restore normal range of glenohumeral motion

Following roentgen therapy a certain number of cases will reveal on roentgenograms a definite diminution of the calcareous deposit and occasionally total resorption of the mass In most instances, however there will be little or no perceptible change These same observations have been noted in untreated cases Thus it is difficult to say whether or not roentgen ray therapy has any specific effect upon the calcareous mass However it is a clinical fact that as long as roentgenographic evidence of calcareous tendinitis exists the patient is likely to develop symptoms of varying severity It is obvious that the most desirable method of treatment is one which will result in complete dispersal and resorption of the calcareous material

Manipulation in subacute and chronic forms should have only one objective rupture of the deposit. If this does not appear feasible nothing will be gained by this

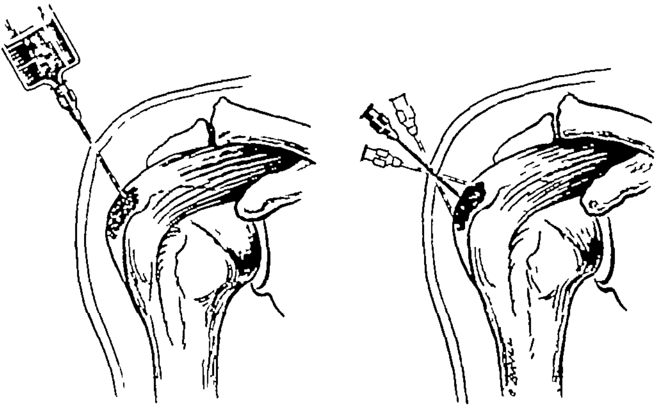

FIG 184 Aspiration and needling of the calcareous deposit in the supraspinatus tendon.

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method of treatment In the presence of advanced periarticular adhesions and contractures of the internal rotators and adductors of the shoulder, severe damage may follow manipulation Tearing and violent stretching of adhesions result invariably in more adhesions also, in long standing cases which have pronounced demineralization of the humerus, fracture of the surgical neck is not an infrequent occurrence The author has seen two such tragedies

Frozen shoulders associated with calcareous tendinitis should be managed in the same manner as frozen shoulders initiated by bicipital tenosynovitis Once the entity is established the bicipital tendon and sheath always are involved After removal of the deposits recovery will be expedited if the biceps tendon is removed from the groove and reattached to the coracoid process (See Treatment of Frozen Shoulder)

OTHER THERAPEUTIC MEASURES

Diathermy is of value only in that it induces hyperemia or increases an existing inflammatory process, thereby favoring rupture of the calcareous mass and the alleviation of pain It has no specific therapeutic value and may increase the intensity of the symptoms until rupture of the bursa occurs After rupture of the floor of the bursa it may accelerate absorption of the calcium particles The same may be said of hot packs which are a valuable adjunct following aspiration and needling or needling alone

Cold packs are definitely indicated during the acute or the subacute stage. They tend to mitigate the inflammatory process and, hence to reduce the tension beneath the sensitive synovial floor of the bursa.

Injection of procaine solution (5 cc.) into the point of maximum tenderness without aspiration or needling sometimes gives dramatic relief In such instances rupture of the calcareous deposit into the bursa is undoubtedly induced as a result of this procedure

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FIG 185 Dislocation of sternoclavicular joint. Reduction is readily achieved by pulling shoulders upward and backward or by making direct pressure over the sternal end of the clavicle Maintenance of the reduction is difficult

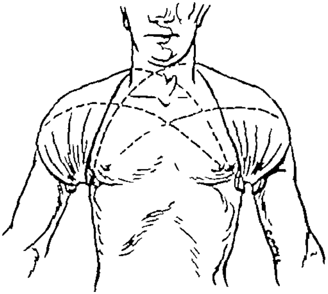


FIG 186 Posterior figure-of-eight plaster-of Paris bandage, 4 inches wide, holding shoulders upward and backward Note cotton wadding in each axilla.

The most popular method is the posterior figure-of-eight bandage Plaster-of Paris bandage is more effective than linen or muslin bandage A large wad of cotton is placed in each axilla, and a small piece of felt in front of each shoulder Both shoulders are then pulled upward outward and backward While the position is being maintained, a posterior figure-of-eight plaster-of Paris bandage four inches wide is applied tightly around both shoulders. The bandaging should be snug enough to maintain the *shoulders upward and backward but should* not embarrass the circulation of the arms

Before the plaster-of Paris bandage becomes hardened the patient is placed in a recumbent position with a folded sheet between both shoulders The operator then makes downward pressure on the front of both shoulders and holds the position until the bandage is sufficiently dry and hardened to maintain the shoulders in the described position The dressing is worn for six weeks Should the arms become cyanotic, the patient is instructed to pull back voluntarily *on the shoulders and abduct the arms from* the side of the body (Fig 186)

Some operators prefer to use the clavicular cross such as is used for fractures of the clavicle This, too, adequately maintains the shoulders in the desired position while healing occurs

Should the above methods fail, the patient may be treated in bed with the arm in lateral traction (90° to 120° abduction) and a sand bag over the sternoclavicular joint (Fig 187) This position reduces the dislocation and maintains reduction. It is retained for three weeks, which period permits sufficient healing of soft tissue to stabilize and prevent redisplacement of the *proximal end of the clavicle when the traction* apparatus is removed A posterior figure-of-eight plaster dressing is then applied, and the patient is made ambulatory The dressing is worn for from three to five additional weeks. Surgical intervention is rarely indicated in fresh traumatic dislocations. Adhesive dressings making pressure over a piece of felt placed over the sternal end of the clavicle are not satisfactory The adhesive strips tend to stretch and become detached thereby allowing redisplacement to occur

Chronic (Old) Dislocations. Not all old dislocations demand treatment In many

7

Dislocations of the Shoulder Joint

DISLOCATIONS OF THE STERNOCLAVICULAR JOINT
DISLOCATIONS OF THE ACROMIOCLAVICULAR JOINT
DISLOCATIONS OF THE SCAPULOHUMERAL JOINT
COMPLICATIONS OF DISLOCATIONS OF THE SHOULDER
OPEN REDUCTION FOR INITIAL DISLOCATION
LUXATIO ERECTA
ACUTE TRAUMATIC POSTERIOR DISLOCATION
OLD DISLOCATIONS
RECURRENT DISLOCATION OF THE GLENOHUMERAL JOINT
POSTERIOR RECURRENT DISLOCATION

DISLOCATIONS OF THE STERNOCLAVICULAR JOINT

Lesions of the sternoclavicular joint are not encountered frequently They may result from falls on the point of the shoulder or in accidents in which great force is applied to the tip of the shoulder from above for example being struck by a falling object Again the lesion may be produced by direct force applied to the sternal end of the clavicle Occasionally it is seen in debilitated individuals in whom there is gradual relaxation of the sternoclavicular and the costoclavicular ligaments allowing subluxation or dislocation of the proximal end of the clavicle

Traumatic dislocations are associated with disruption of the sternoclavicular ligaments the interarticular disk retaining its attachment to the clavicle and following it in the dislocated position In forceful downward displacements of the shoulder the proximal end of the clavicle is forced downward and backward until it impinges upon the first rib which acts as a fulcrum. If the force continues the first rib levers the inner end of the clavicle upward and forward tearing the sternoclavicular ligaments This is the most common mechanism of production of sternoclavicular dislocation

The final position of the end of the clavicle depends upon the direction of the dislocating force. It may be displaced upward downward forward or backward The most common displacement is forward rarely backward Backward displacement results from direct violence applied to the sternal end of the clavicle or indirect forces driving the shoulder forward and inward The writer has seen one instance of backward dislocation resulting from a direct blow with the butt of a rifle on the proximal end of the clavicle which was driven into a retrosternal position causing pressure on the trachea and the great vessels and producing dyspnea and cyanosis

Like the acromioclavicular joint, the stability of the sternoclavicular joint depends upon its ligamentous structures and not on its bony configuration Reduction of the deformity is accomplished readily although *maintenance of reduction is extremely* difficult (Fig 185)

Treatment

Recent Dislocation. Reduction is readily accomplished by the same maneuvers employed to reduce fractures of the clavicle. Replacement of the sternal end of the clavicle occurs when the shoulder girdle is pulled upward outward and backward Maintenance of reduction is achieved by methods employed for fractures of the clavicle.

the first rib, keeping within the periosteal tube and close to the bone to avoid injuring the soft tissue structures posteriorly Into the eye of the needle is threaded a piece of silk with a strip of fascia lata (from eight to ten inches long and one half inch wide) attached to the other end The fascia is pulled around the rib and, by the same maneuver around the clavicle

The process is repeated so that two loops of a continuous strip of fascia are passed around the clavicle and the first rib The ends are then pulled tight and sutured to one another by interrupted silk or cotton sutures. Medial to the first fascial loop a second strip of fascia is passed around the first rib in the same manner as above It is passed through a vertical drill hole in the clavicle. The ends are drawn taut and sutured to one another

Postoperative Treatment. A Velpeau bandage is used to protect the shoulder for three or four weeks A regimen of physical therapy and exercises is then begun Optimum restoration of function is attained in from eight to ten weeks

Arthrodesis of the sternoclavicular joint never should be done, because marked restriction of elevation of the arm results. Disability resulting from failure of reconstructive methods or arthritis may be relieved in a large measure by excision of one or one and one half inches of the proximal end of the clavicle.

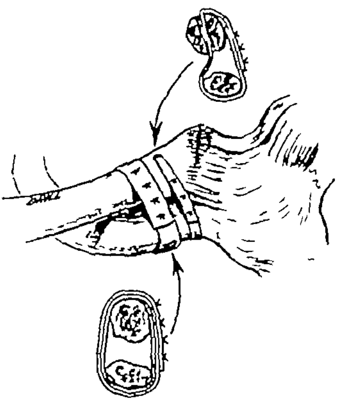


Fig 188 Reconstruction of sternoclavicular ligaments. Operation of Speed and Smith.

DISLOCATIONS OF ACROMIOCLAVICULAR JOINT

Being located at the tip of the shoulder the acromioclavicular joint is vulnerable to such repeated trauma as direct forces applied to the top of the shoulder from above (falling objects) or falls on the point of the shoulder Being a hinge joint, the acromioclavicular joint depends upon strong ligaments for stability The articular surface of the clavicle faces downward outward and backward while that of the acromion looks upward inward and forward Little stability is provided by the articular capsule and the acromioclavicular ligament, the joint depending entirely upon the coracoclavicular ligaments (conoid and trapezoid ligaments) for its integrity Depending upon the degree of disruption of the ligamentous apparatus of this joint, two lesions may occur (1) subluxation and (2) complete dislocation.

Subluxation of Acromioclavicular Joint

Minor injuries may result in tearing of the articular capsule and the acromioclavicular ligament Both the conoid and the trapezoid ligaments remain intact Usually there is some drooping of the shoulder and slight anterior displacement of the acromion (Fig 191) Urist recorded that if in the anteroposterior roentgenograms there is widening of the joint space, the clavicle is displaced posteriorly This is true even when the superior and the inferior surfaces of the clavicle and the acromion appear to be in normal anatomic relationship The

instances the lesion is perfectly compatible with good painless function of the shoulder girdle However, in other instances there is pain and restriction of elevation and abduction of the arm and the appearance of the deformity may be objectionable In these cases operative procedures have been designed to effect a cure Conservative closed methods are valueless Most open methods attempt to anchor the end of the clavicle to the first rib (occasionally to the second rib), the manubrium or to both with fascia lata

All procedures are difficult and tedious Profuse bleeding may add to the difficulties of the operation Not infrequently the joint is so disorganized that the interarticular disk must be removed, and secondary degenerative changes following repair are unavoidable In the face of such difficulties some operators prefer to excise subperiosteally *one to two inches of the sternal end* of the clavicle Such a procedure is compatible with good painless function and decreases the period of recovery without immobilization of the extremity

Speed's operation for reconstruction of the sternoclavicular ligaments has given the writer satisfactory results Essentially, it anchors the mesial end of the clavicle to the first rib by two strips of fascia lata (Fig. 188) Bankart's operation is also useful to repair chronic dislocations of the sternoclavicular joint (Fig 189)

Operative Technic (Speed) A straight skin incision from two and one half to three inches long is made along the inferior border of the proximal end of the clavicle beginning just lateral to the midline of the manubrium Approximately two inches of the mesial end of the clavicle is exposed by stripping it subperiosteally (At this point the writer investigates the sternoclavicular joint If the meniscus is found to be disrupted or degenerated, it is excised)

Part of the pectoralis major muscle fibers arising from the clavicle, the sternum and the first and the second costal cartilages are *divided and reflected downward and* outward bringing into view the first and the second costal cartilages The periosteum on the first rib is cut horizontally and the rib and the costal cartilage are exposed subperiosteally for about two inches

An aneurysm needle is then passed around

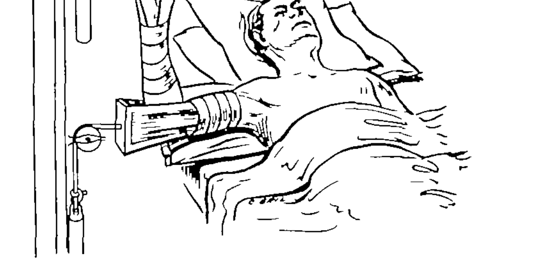


Fig 187 Lateral arm traction for treatment of fresh sternoclavicular dislocation.

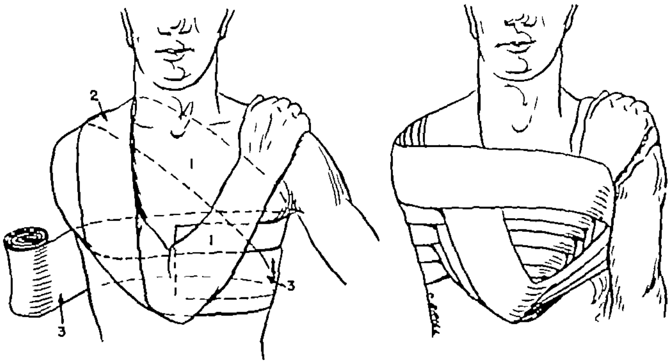


FIG 190 Velpeau bandage.

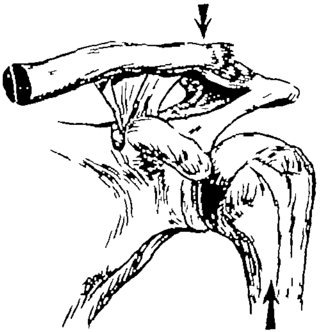
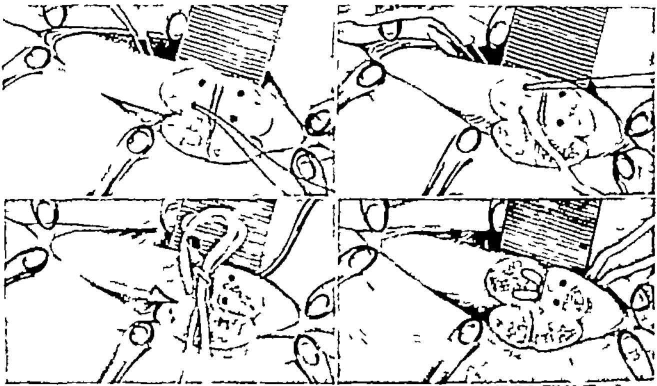


FIG 191 Subluxation of acromioclavicular joint.

FIG 192 Dislocation of acromioclavicular joint.

acromion is widely separated from the clavicle (Fig 192) Occasionally a segment of the outer end of the clavicle may be fractured and follows the acromion downward As in subluxation of this joint the displacement is reduced readily by elevating the scapula by pushing the elbow upward and backward, at the same time pressing the clavicle downward However, release of all support results in recurrence of the deformity

Diagnosis of the lesion by clinical examination is not difficult Inspection discloses a droop of the shoulder downward



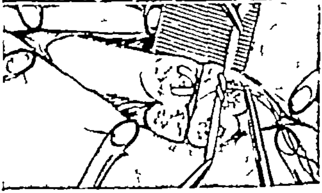


FIG 189 Bankart's operation for chronic dislocation of the sternoclavicular joint. (*Top left*) Loop of silkworm gut passing through the lower hole of the clavicle One end of the fascial strip is threaded into the loop in readiness for pulling through the hole (*Top right*) The other end of the fascial strip being pulled through the upper hole in the clavicle (top left) (*Center left*) Curved aneurysm needle with the two ends of the fascial strip threaded through the eye prior to being pulled through (center right) (*Center right*) The fascial strip pulled through to the back of the joint. (*Bottom*) The ends of the fascial strip have been brought through the holes in the sternum and tied and are held tight by an assistant while the surgeon sews the joint firmly with linen thread sutures. (Brit. J Surg. 26 321 322)

same observer further noted that if the distal end of the clavicle was free floating (ballottement) after 3 weeks of conservative treatment this form of therapy would not effect a cure The prime factors responsible for failure were interposition of the torn meniscus remnants of the torn acromioclavicular ligaments and detached portions of articular cartilage

In subluxation of the joint, anteroposterior roentgenograms of both shoulders made with the patient standing and the arms at the side disclose that the interval between the clavicle and the coracoid process is the same on both sides Pain may not be severe but tenderness always can be elicited by pressure over the joint. Although the deformity may be slight in most instances a definite prominence of the clavicle can be demonstrated The displacement is reduced readily by pressing the outer end of the clavicle downward while the elbow is pushed upward and backward

Complete Dislocation of Acromioclavicular Joint

This lesion is the result of violent trauma producing complete rupture of the coracoclavicular and the acromioclavicular ligaments As the shoulder drops forward, the

Fig 194 Complete dislocation of the acromioclavicular joint The interval between the clavicle and the coracoid process has been greatly increased.

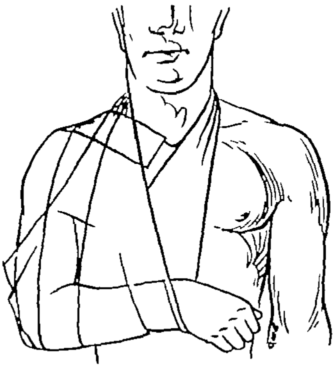


Fig 195 Stimson adhesive dressing for subluxation of the acromioclavicular joint.

clavicle, down the arm anteriorly, around the elbow, up the arm posteriorly and across the outer third of the clavicle anteriorly (Fig 195) Four or 5 such strips are superimposed on each other This strapping is reinforced every 4 or 5 days by adding another strip

Immobilization is maintained for from 3 to 5 weeks Active motion within the limits of the dressing should be carried out at the shoulder the elbow and the fingers Free use of the arm is permitted after all fixation is removed Physical therapy at this time in the form of radiant heat and gentle massage adds to the comfort of the patient

Complete Dislocation of Acromioclavicular Joint (Acute) Due to total disruption of the coracoclavicular ligaments conservative measures have been very unsatisfactory on the whole However many workers advocate such methods as Stimson's adhesive dressing (or various modifications of it) the abduction plaster jacket and numerous braces splints and harnesses to maintain reduction until healing is complete In the hands of many including the writer these measures have proved to be inadequate.

The view that complete dislocations are treated best by operative intervention is becoming increasingly popular, and several procedures have been devised to restore the integrity of the acromioclavicular joint

Transfixion of the Joint with Wires This is an excellent method in acute complete dislocations Done blindly or even with fluoroscopic control, the procedure is not without danger Unpleasant complications are avoided if it is done under direct vision after exposure of the joint. Many complete dislocations, even after adequate re-establishment of the ligamentous structures are followed by arthritis of the joint, which may be responsible for much pain and disability Degeneration of a traumatized meniscus (if present) is in a large measure the cause of the complication Exposure of the joint permits visualization and excision of the meniscus and the removal of other tissue debris thereby reducing the chance of such undesirable sequela

Technic A straight skin incision is made starting on top of the clavicle ½ inch to the inner side of the acromioclavicular joint

and forward and a prominent outer end of the clavicle (Fig 193) Pressure over the joint elicits marked tenderness A groove is palpable between the outer end of the clavicle and the acromion which is not palpable on the unaffected side If the acromion is steadied with one hand, the outer end of the clavicle can be displaced with ease up and down forward and backward, with the index finger and the thumb of the opposite hand

Roentgenographic examination reveals upward displacement of the clavicle and greater distance between the clavicle and the coracoid process on the injured than on the uninjured side (Fig 194)

Treatment of Recent Lesions of Acromioclavicular Joint

Reduction of the displacement is accomplished easily but maintenance of reduction is extremely difficult.

Subluxation in which the coracoclavicular ligaments are intact is treated adequately by Stimson s adhesive dressing

Stimson Adhesive Dressing The extremity is suspended by a collar-cuff sling. One piece of felt is placed over the outer end of the clavicle, another is placed below the elbow, covering the proximal third of the ulna, and a pad of cotton is placed in the axilla. An adhesive strapping is then applied, so that the clavicle is pressed downward firmly, and the elbow is pushed upward This elevates the scapula and brings the acromion up to the clavicle Reduction must be maintained manually, while the dressing is being applied, by pushing upward on the humerus at the elbow and downward on the clavicle Skin irritation is prevented by applying a coating of benzoin tincture to the skin before applying the adhesive strips A second strip of adhesive 3 inches wide and 4 feet long starts posteriorly at the level of the waist and is brought upward over the outer end of the

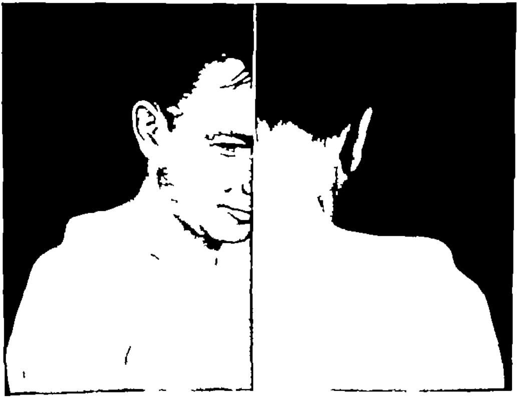


Fig 193 Anterolateral and posterior views of a dislocated acromioclavicular joint, 1 month s duration. Observe the prominent outer end of the clavicle and drooping of the shoulder

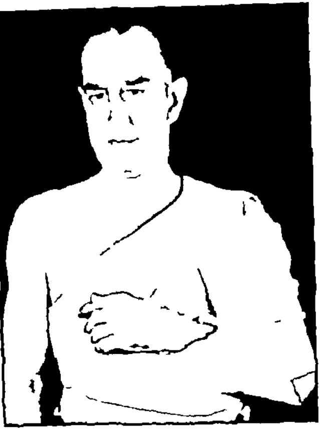


FIG 198 Plaster-of Paris shoulder swathe used instead of a Velpeau dressing to immobilize the arm

FIG 199 The outer end of the clavicle has been resected for an old acromioclavicular dislocation.

locations However it is now also widely used in fresh dislocations and the results are extremely satisfactory As has been noted by many observers the shoulder girdle, following excision of the outer end of the clavicle does not regain complete function The great majority of the patients complain of some weakness a sense of instability and fatigue following strenuous activity Nevertheless normal range of painless motion is restored the deformity is minimized and the convalescence is greatly shortened. It is particularly justified in individuals who are not employed in laborious occupations

Technic The distal end of the clavicle and the acromioclavicular joint are exposed by a curved incision. First approximately 1 to 1½ inches of the outer end of the clavicle is stripped subperiosteally of all soft tissue and then excised with a Gigli saw or bone-cutting forceps The meniscus and other remnants of the acromioclavicular ligaments and the capsule are removed The remaining periosteum is utilized to cover the exposed raw surface of the end of the clavicle (Fig 199)

Postoperative Management Complete rest of the extremity is desirable for about a week during which time the shoulder is protected by a plaster-of paris shoulder swathe or by a Velpeau dressing At the end of this period soft tissue healing has progressed sufficiently to allow painless motion at the shoulder girdle. The patient is now permitted free use of the arm and progressive muscular exercises are begun This phase of the treatment should aim for full restoration of muscle tone and power to stabilize the shoulder Optimum restoration of function is attained in from 4 to 6 weeks.

RECONSTRUCTION OF CORACOCLAVICULAR LIGAMENTS (*using part of the conjoined tendon of the short head of the biceps and the coracobrachialis muscles*) Several operations have been conceived to re-establish

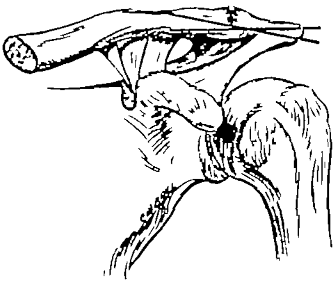


Fig 196 Transfixion of acromioclavicular joint by two threaded wires

and continues laterally to the tip of the acromion The incision is deepened to the bone and the soft tissues are reflected by sharp dissection from the top of the acromion and the acromioclavicular joint All remnants of capsular and acromioclavicular ligamentous tissue which may have dropped into the joint are removed together with the meniscus Under direct vision while the clavicle is being held firmly in its normal anatomic position two stout Kirschner wires are passed through the acromion across the joint space into the clavicle

The wires penetrate the distal end of the clavicle for approximately 1 or 1½ inches. Their ends are then turned up and cut close to the edge of the acromion but left long enough to facilitate their withdrawal The superior portion of the capsule and the acromioclavicular ligament is repaired as much as possible, and the wound is closed, leaving the ends of the wire beneath the skin

Postoperative immobilization is accomplished best by a Velpeau dressing or a plaster swathe (Fig 198), which is worn for 4 weeks after which the arm is carried in a sling for 2 additional weeks The wires may be removed at the end of 6 or 8 weeks at which time the patient is permitted free use of the extremity

Instead of Kirschner wires, threaded steel pins may be utilized to transfix the joint. These have less tendency to migrate than the unthreaded pins or wires (Figs 196 and 197)

Excision of Outer End of the Clavicle. This method was designed originally by Mumford and Gurd independently for treatment of chronic acromioclavicular dis-

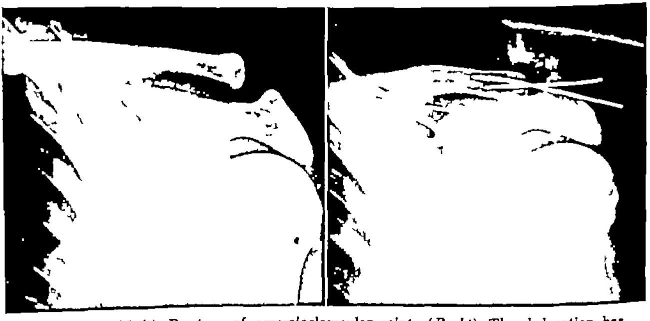


Fig 197 (*Left*) Rupture of acromioclavicular joint (*Right*) The dislocation has been reduced and the acromioclavicular joint has been transfixed by two threaded wires the ends of which were cut off under the skin

observed that the tendinous origin of the conjoined tendon is rather broad and about 3½ or 4 inches long This tendinous segment is split in half longitudinally for its entire length The distal end of the outer half of the tendon is divided transversely, while its proximal end remains attached to the coracoid process

The next step comprises exposure and reduction of the dislocation Through the upper arm of the incision the soft tissues are stripped by sharp dissection from the superior surface of the acromion and the outer end of the clavicle All tissue debris, including the meniscus and the torn ligamentous and capsular tissues, are removed from the joint cavity By firm pressure *downward and forward on the clavicle* the dislocation is reduced and maintained by passing two Kirschner wires or threaded wires through the acromion across the joint space and into the clavicle under direct vision. The acromioclavicular ligament is sutured in the best manner possible

Next, that portion of the clavicle immediately above the coracoid process is stripped subperiosteally The reflected portion of the conjoined tendon is passed around the clavicle subperiosteally and sutured to itself The enveloping tube of periosteum is closed and sutured to the tendon within. The arm is immobilized in a plaster-of paris shoulder swathe for 6 weeks Graduated exercises and physical therapy follow and the wires may be removed at the end of 8 or 10 weeks Maximum restoration of function is attained in from 12 to 16 weeks.

The writer has found this operation to be superior to other procedures employing strips of fascia lata and performs it chiefly for chronic rather than fresh dislocations Calcification of fascia utilized in the reconstruction of the coracoclavicular ligaments is a frequent complication To date this has not occurred in any of the cases in which the conjoined tendon was used However it is feasible that calcification may occur One must appreciate that calcification of tissues in the coracoclavicular interval is a common complication of complete dislocation, even without surgical intervention The subsequent synosteosis limits elevation and abduction of the arm and is responsible for considerable pain and stiffness in the shoulder

Transfixion of the Coracoid Process and the Clavicle with a Screw This method has been popularized by B Bosworth, Vere-Hodge and Watson Jones Essentially, it consists of maintaining reduction by means of a lag screw passed through the clavicle into the coracoid process It has failed to meet the expectations of many of its supporters because the procedure is comparable with arthrosis of the acromioclavicular joint. *Motion at this joint is necessary* for complete elevation above the horizontal This is accomplished by rotation of the clavicle in its long axis (Inman, Saunders and Abbott) Coracoclavicular transfixion eliminates all acromioclavicular motion thereby causing marked impairment of elevation of the arm.

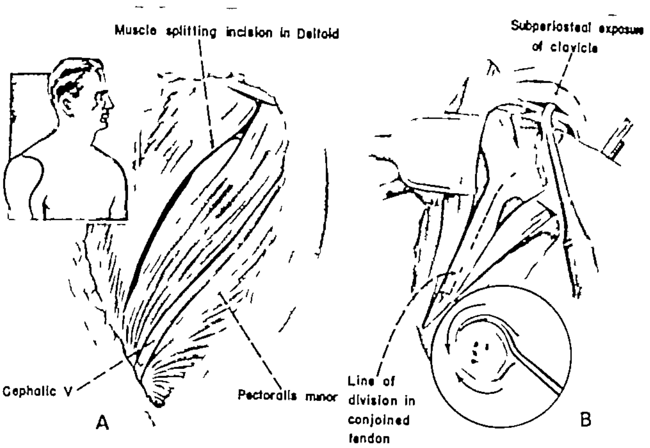
Treatment of Old Acromioclavicular Dislocations

Not all old lesions demand surgical interference In some individuals the dislocation causes no impairment of normal activity In others, there is a pronounced disability characterized by a reduction of shoulder movements and by pain

Excision of the outer end of the clavicle, as previously described is applicable to all age groups and gives uniformly good results It is especially indicated in individuals past middle life and in the aged

In young athletic individuals and in those employed in strenuous occupations repair of the coracoclavicular ligaments is preferred Repair is achieved either by using the conjoined tendon of the short head of the biceps and the coracobrachialis muscles, as described above, or fascia lata as described by Henry and by Bosworth or by the method of Bunnell (Fig 201)

Restoration of normal anatomic relations



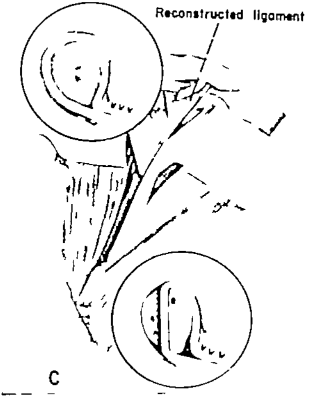


FIG 200 Reconstruction of coraco-clavicular ligament (Vargas modified)

the integrity of the ligamentous apparatus of the acromioclavicular joint In the main strips of fascia lata are utilized to reconstruct the disrupted ligaments The operation devised by Bunnell and by Henry have become increasingly popular The author has modified the technic of Vargas in which a portion of the conjoined tendon of the coracobrachialis and the short head of the biceps brachii muscles are used to reconstruct the coracoclavicular ligaments

Technic (Method of Vargas—Modified) An S shaped skin incision is made beginning at the tip of the acromion continued medially along the lower margin of the clavicle and skirting the outer edge of the coracoid process (Fig 200) The incision is deepened through the anterior fibers of the deltoid

Retraction of the deltoid muscle medially and laterally brings into view the coracoid process and the tendinous origin of the conjoined tendon of the short head of the biceps and the coracobrachialis muscles The interval between the deltoid fibers is developed proximally as far as the inferior border of the clavicle

At this stage of the operation, it will be

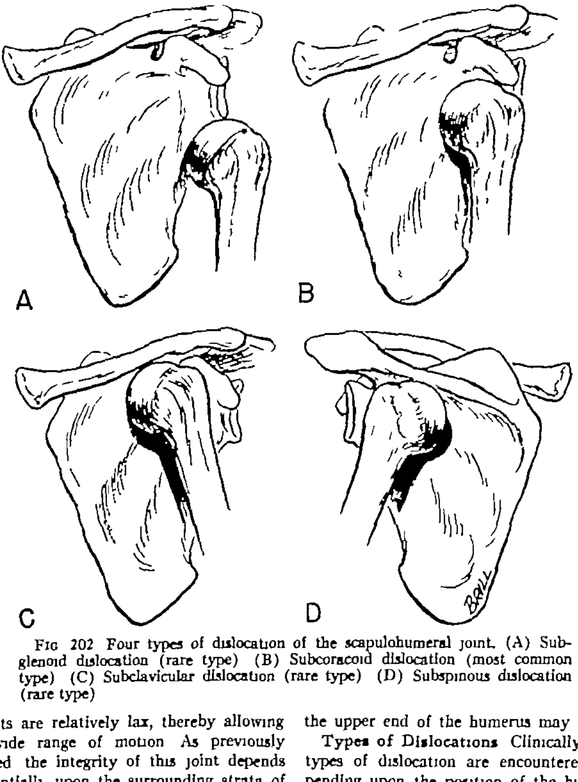


FIG 202 Four types of dislocation of the scapulohumeral joint. (A) Subglenoid dislocation (rare type) (B) Subcoracoid dislocation (most common type) (C) Subclavicular dislocation (rare type) (D) Subspinous dislocation (rare type)

ments are relatively lax, thereby allowing a wide range of motion As previously noted the integrity of this joint depends essentially upon the surrounding strata of muscles and atmospheric pressure Moreover its unprotected position renders the joint extremely vulnerable to trauma

Functionally the glenohumeral joint possesses a wide range of movements, made possible not only by its bony configuration but also by a delicate, intricate system of neuromuscular balance and co-ordination If disturbed by unguarded sudden motions or violent injury dislocation or fracture of the upper end of the humerus may result

Types of Dislocations Clinically four types of dislocation are encountered depending upon the position of the humeral head in relation to the glenoid cavity The head may lie below the glenoid cavity (subglenoid dislocation), beneath the coracoid process (subcoracoid dislocation) occasionally under the clavicle (subclavicular dislocation), and in rare instances the head occupies a position below the acromion or the spine of the scapula (posterior or subspinous dislocation) Subcoracoid is the most frequent type of dislocation The sub-

Fig 201 For dislocation of acromioclavicular joint. Method of placing 12 inch graft of fascia lata to reproduce conoid and trapezoid ligaments. (*Top left*) The anatomy of the conoid and trapezoid ligaments the positions of the three holes in the bone and the fascial graft (indicated by rubber tube) in place but not yet drawn up (*Top center*) Fascial graft (indicated by rubber tube) in place and sutured as seen from the front. (*Top right*) Posterior view (*Bottom left*) Superior view showing extra reinforcement of the joint capsule (*Bottom center*) Inferior view (*Bottom right*) Patient on whom this operation was performed 6 months previously Although he is lifting a heavy anvil, no difference can be detected in his two acromioclavicular joints. The original anatomy is reconstructed and the function is normal (Surg Gynec. & Obst. 46 563)

in the acromioclavicular joint does not ensure a painless freely moving shoulder girdle Pain and disability may persist even after operative re-establishment of the torn ligaments Degenerative changes of varying degrees in the joint are to be anticipated

Arthrodesis of the acromioclavicular joint never should be done because of the subse quent restriction of elevation Arthritis re gardless of the degree or disruption of the acromioclavicular joint does not justify an arthrodesis Excision of the outer end of the clavicle is the procedure preferred for such cases

DISLOCATIONS OF THE SCAPULOHUMERAL JOINT

Acute Dislocations

General Considerations. Dislocation at the scapulohumeral joint is a frequent lesion estimates indicating that from approximately 40 to 60 per cent of all disloca tions occur at this joint The lesion is encountered most frequently in the late teen years and after the age of 20 but they may occur at any age Young athletic males are usually affected but the condition may occur in females It is a rarity in children

Several anatomic and functional features of the shoulder are responsible for the frequency of dislocation Anatomically the bony architecture of the joint favors in stability Only a very small area of the large spherical humeral head articulates with the shallow glenoid cavity at any one time The fibrous capsule is loose and redundant becoming taut only at the extremes of the arcs of motion Roughly its surface area is twice that of the humeral head Likewise the various reinforcing capsular liga

glenoid form is next in frequency It is reasonable to assume that many subcoracoid lesions were first subglenoid and by inward and forward movement of the humeral head or the drive of the *dislocating force* were converted into subcoracoid dislocations (Fig 202)

Luxatio erecta is the rarest form The arm is fixed to the side of the head and points directly upward, while the forearm rests on the top of the head the humeral head *lies in a subglenoid position* The lesion is produced by hyperabduction of the arm while an axial force drives the head of the humerus directly downward through the capsule

Mechanism of Production of Dislocation

Survey of the literature discloses many diversified concepts of the mechanisms of dislocation, and there is no general agreement among the earlier observers. This confusion stems in part from the difficulty in obtaining an accurate account of the movements and the position of the arm at the time of the injury, and in part from the lack of comprehension of the normal movement of the glenohumeral joint Codman has given us an unequivocal mechanism of dislocation which is based on a scientific analysis of the normal functions of the shoulder joint He noted that 'no matter in what degree of rotation you start to raise your arm and no matter in what plane you raise it the capacity for rotation will be less and less *as the arm ascends until* in complete elevation tuberosities and processes will be locked in a fixed position This position was designated the pivotal position In order to reach the pivotal position in the sagittal plane the arm must be rotated internally and in the coronal plane rotated externally

If during elevation of the *arm in the* sagittal plane internal rotation is prevented the humerus will impinge upon the acromion which acting as a fulcrum will lever the head of the humerus out of the glenoid cavity or produce a break in the bone The same is true *if* external rotation of the humerus is prevented when the *arm is being* elevated in the coronal plane Hyperabduction of the arm beyond the limits of the *pivotal position* will also result in dislocation or fracture of the humerus (Fig 203) It is apparent that the position of safety is the pivotal position During forward or lateral falls, the ascending arm instinctively rotates in the right axis to reach this position However, if rotation in the correct *plane is prevented, or if the falls* are violent and sudden, catching the muscles off guard in a relaxed state before they can rotate the humerus into the position of safety disruption of the glenohumeral joint is inevitable.

One can demonstrate readily on a subject that the scapulohumeral joint will lock in *different positions, depending upon the* degree of rotation of the humerus This is true, regardless of the relation of the humerus to the scapula, whether it be in the anatomic position (the arm at the side with the palm facing forward), at the horizontal or in the pivotal position where no rotation is possible If the limits of this *locked* position are exceeded the humerus obtains a fulcrum on the edge of the acromion, and dislocation or fracture of the humeral head ensues

The mechanism of dislocation when the falling patient exerts force on the outstretched arm is the same as when leverage is applied on the arm with the body in a fixed position Anterior or posterior dislocations will occur depending upon the direction of the disruptive forces As a rule anterior dislocation occurs if hyperabduction is continued after the arm has reached the pivotal position or if rotation is prevented after the arm has ascended to a point above the horizontal Posterior dislocation occurs when the arm is below the horizontal *and is rotated internally* beyond the limits of the locked position

Analysis of the many different combinations of elevation and rotation of the humerus which are likely to produce dislocation indicates that clinically, the mechanism

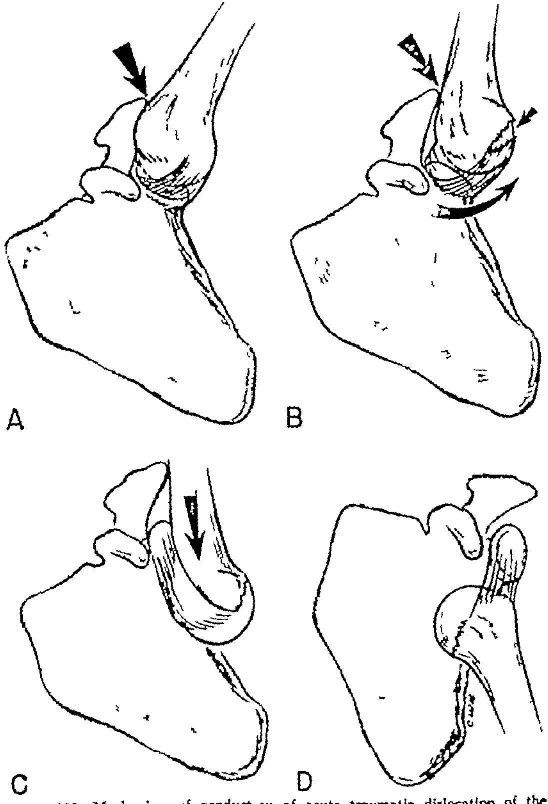


Fig 203 Mechanism of production of acute traumatic dislocation of the scapulohumeral joint by hyperabduction of the arm (A) Arm in the pivotal or safety position. (B) Humerus is forced into hyperabduction impinging against the acromion which acts as a fulcrum and levers the head of the humerus out of the glenoid cavity note the tearing away of the inferior portion of the capsule from the neck of the humerus. (C) Head leaves glenoid fossa through rent in capsule stretching the rotator cuff across the glenoid cavity (D) Arm at the side with head of humerus assuming first a subglenoid position.

This is the most common mechanism of anterior dislocations (Fig 204)

Adams lists five types of injuries which may be responsible for initial dislocation

1 Fall on the abducted arm (without hyperabduction)

2 Direct blows on the head of the humerus from behind

3 Hyperextension of the abducted arm

4 Excessive external rotation in abduction

5 Hyperabduction (causing inferior dislocation)

Critical analysis of the above types make it clear that all of them can be explained by Codman s postulates of dislocation

Pathology of Acute Anterior Dislocation

Much has been recorded on the pathology of acute anterior dislocation Many of the proposed concepts disclose total disagreement thereby giving rise to considerable confusion. This occurs because hitherto many of the postulates of dislocation were based on pure conjecture rather than actual visualization of the affected tissues at the time of the injury According to most observers, avulsion of the labrum glenoidale the fibrous capsule and the glenohumeral ligaments from the antero-inferior aspect of the bony brim of the glenoid fossa represents the most frequent pathologic lesion. Many observers (Ivan Palmar Adams King Gallie and Eyre Brook) are of the opinion that a compression fracture of the posterior aspect of the head of the humerus may occur at the time of the first dislocation and recurrences of the fracture are likely

Fracture of the bony rim of the glenoid fossa has been described by many investigators Bankart emphasizes that there are two distinct types of traumatic dislocations He contends that the ordinary traumatic lesion is an inferior dislocation, the head of the humerus passing through a rent in the capsule It is Bankart s belief that this lesion heals readily and is not followed by recurrences The second type is anterior dislocation associated with detachment of the labrum and the capsule from the anterior *margin of the glenoid cavity* Frequently, this lesion is followed by recurrences, because the detached labrum fails to reattach itself to the glenoid rim

It is obvious that clarification of the pathology of acute dislocation can be attained only by exploration of the shoulder joint at the time of injury Such exploration was performed in 18 fresh anterior dislocations before reduction No cases complicated by fracture of the humeral head are included in this study Ages of patients ranged from 18 to 64 years, 6 were over 45, and the remainder were under 35 years of age All patients were male

In all instances roentgenographic examination disclosed a subglenoid or subcoracoid dislocation Care was taken to hold the humeral head in its abnormal position until it was visualized

Pathologic Observations

Position of Humeral Head in Relation to the Glenoid Cavity In two cases the humeral head was found in a subglenoid position, resting immediately below the inferior rim of the glenoid cavity In 16 cases it occupied a subcoracoid position

Position of Humeral Head in Relation to Capsule

Head Outside of Capsule In six instances the heads were outside of the fibrous capsules. In four cases it was noted that the inferior capsule had been torn away from the neck of the humerus, allowing the head to escape from within the capsule Two of the four shoulders demonstrated the rent in the capsule to be continuous with a tear in the substance of the subscapularis tendon where it inserted into the lesser tubercle Inspection of the interior of the joint cavity in all four shoulders disclosed the labrum and the glenohumeral ligaments to be intact

The remaining two humeral heads revealed massive cuff tears, both heads being outside the joint cavity lying beneath the coracoid process It was significant that both

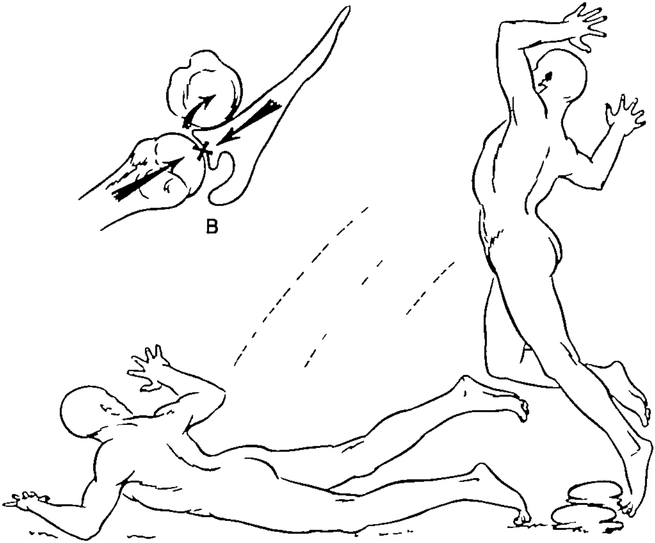


FIG 204 (A) Dislocation caused by fall on outstretched arm producing an impacting force against the glenoid cavity (B) Resultant force is created which acts through the plane of glenohumeral joint and allows head to dislocate anteriorly on the neck of the scapula in a subcoracoid position

of production is not constant Whether some of these mechanisms are more likely to initiate recurrent dislocation than others is discussed under Pathology of Recurrent Dislocation.

Other factors which play a significant role in the mechanism of dislocation are (1) the action of the adductor muscles and (2) the impacting or telescoping force applied to the glenoid cavity through the bony axis of the humerus during a fall on the outstretched arm or the partially abducted elbow Codman holds that the contracted adductor muscles (pectoralis major and latissimus dorsi) do not create a fulcrum but promote dislocation by acting as internal rotators thereby preventing external rotation of the humerus when the arm is ascending in the coronal plane

Falls on the outstretched arm or on the partially abducted elbow create an impacting or telescoping force which is resisted by the glenoid cavity A resultant force ensues which acts through the plane of the glenohumeral joint. If the force is of sufficient severity the humeral head is forced forward on the anterior surface of the neck of the scapula usually in a subcoracoid position.

of bone devoid of soft tissue attachments, lay within the joint cavity In another shoulder, a piece of the rim of the glenoid was found with a egment of the labrum still adherent to it (Fig 205) Six shoulder joints disclosed no abnormalities of the labra, but all the glenohumeral ligaments and the anterior portions of the capsules suffered extensive tearing and attenuation

It was interesting to note in all these specimens that the head came to rest finally in the subscapularis recesses Because of the laxity of the capsule and the glenohumeral ligaments one can apprehend how the boundaries of the above recesses can stretch or tear readily if necessary, to admit the humeral head In no instance, however, was the head found out of the confines of the fibrous capsule This is explainable by the topographic anatomy of this region As noted in Chapter 3, in the greater majority of cases the upper two-thirds of the anterior portion of the fibrous capsule does not insert directly into the labrum and the rim of the glenoid cavity but is continued mesially as far as the subcoracoid region where it is reflexed along the anterior aspect of the neck of the scapula to the capsular margin of the labrum

This outpouching of the fibrous capsule forms the subscapularis recesses, either one or two depending upon the presence or the absence of a middle glenohumeral ligament (Fig 227)

From this study it is apparent that most dislocations are intracapsular, that the head comes to rest in the bursal recesses and not out of the joint capsule

No defects comparable with fresh compression fractures or contusions were demonstrable in the posterior aspect of the humeral heads

Nicola s comprehensive study on a similar series of cases adds another important observation to those recorded above He noted that in 22 cases the capsule was torn from *the neck of the scapula* and in 5 cases it was torn from the humerus In the former group the lesion was the result of abduction

FIG 205 Fragments of torn labrum and pieces of glenoid brim removed from within joint cavity in a case of acute dislocation of the glenohumeral joint.

plus an impacting force acting against the glenoid cavity In the latter group simple hyperabduction of the arm was responsible for stripping the capsule from the neck of the humerus

From the afore mentioned investigation in initial dislocations without fractures the pathologic observations may be summarized as follows

1 Stripping the capsule from the inferior aspect of the humeral head

2 Disruption of the glenohumeral ligaments and attenuation of the boundaries of the subscapularis recesses

3 Shearing the labrum glenoidale from the anterior glenoid rim

4 Fracture or maceration of the labrum glenoidale

5 No involvement of the labrum

6 Stripping labrum capsule and periosteum from the anterior surface of the neck of the scapula

7 The humeral head lies extracapsular when it is forced through a rent in the capsule made by stripping the capsule from the humerus or when it is driven through a tear in the cuff

8 The humeral *head is intracapsular* when it lies within the confines of the subscapularis recesses

9 Varying degrees of tears of the rotator cuff involving chiefly the subscapularis and

these patients were over 60 years of age In one the cuff tear involved the superior half of the subscapularis tendon, the supra spinatus and the infraspinatus tendons In the other in addition to avulsion of the supraspinatus and the infraspinatus portion of the cuff from the humeral head, a long longitudinal split was demonstrable in the interval between subscapularis and supra spinatus tendons In both instances the biceps tendon was found outside of the groove stretched over the greater tuberosity It was apparent that the heads were forced through the traumatic defects in the cuffs In the first case the avulsed cuff lay in front of the glenoid cavity like a curtain It became obvious that closed reduction in this case would fail because of the interposition of the torn rotator cuff Inspection of the interior of the joints fails to exhibit any abnormalities of the fibrous capsule, the labrum glenoidale or the glenoid rim that could not be explained as degenerative changes associated with usage and senescence

Head Inside of Capsule Twelve shoulder joints exhibited the humeral heads on the anterior aspect of the neck of the scapula but within the joint capsule In all instances the subscapularis muscle was stretched severely as it passed over the displaced head its tendon fibers were blanched and many showed tiny transverse superficial tears Moreover the other rotators were all under tremendous tension as they were pulled tightly over the empty glenoid fossa In all instances the supraspinatus muscle appeared to be under the greater strain The infraspinatus and the teres minor although under less strain were angulated sharply over the posterior edge of the glenoid fossa

Four cuffs disclosed a complete tear Of these two involved the upper half of the subscapularis tendon and the supraspinatus tendons one the supraspinatus and the infraspinatus tendons and one only the supraspinatus tendon Although no obvious tears were discernible, all the remaining cuffs were stretched severely across the glenoid cavity In one cuff which revealed a tear, the biceps tendon was found outside of the intertubercular sulcus lying against the intact edge of the infraspinatus tendon.

In order to visualize adequately the glenoid fossa and the structures in its anterior aspect, the dislocation was first reduced The subscapularis tendon and with its capsule was then divided 1 cm. from its insertion into the lesser tuberosity and was retracted medially It was of interest and *most significant to note the diversity of* pathologic observations discernible in this region of the joint It was obvious that all soft tissue elements were stretched to accommodate the head By passing a probe along the anterior margin of the glenoid cavity beneath the articular edge of the labrum or along its capsular margin in no instance was it possible to find a direct communication between the interior of the joint and the exterior

As a rule, the inferior and the middle glenohumeral ligaments elicited evidence of pronounced trauma particularly the inferior ligament which was either completely torn from its labral attachment or markedly attenuated Two inferior ligaments were split longitudinally Several shoulders disclosed ruptures of the labral ends of the middle ligaments allowing them to dangle freely within the joint cavities from their intact humeral attachments Varying degrees of separation of the labra were noted In six shoulders the labra were separated completely from the anterior portion of the glenoid rim exposing the raw bony surface. However in all instances the reflexed capsule over the neck of the scapula was intact Three of these 6 cases also demonstrated crushing and shredding of the labra leading one to conclude that the structures were subjected to great shearing strains. Two cases disclosed stripping of the inferior ligament from its labral attachment together with the reflexed capsule from the neck of the scapula. In one instance with a detached labrum the bony rim of the glenoid cavity was fractured completely and the fragment

Pain and muscle spasm may preclude a diagnosis of loss of motor power in the deltoid muscle prior to reduction At this time, the only significant evidence of circumflex nerve affection is the presence of a patch of hypo-esthesia in the sensory distribution of the nerve through its cutaneous branch, the upper lateral cutaneous nerve of the arm (Fig 207) As a rule, impaired skin sensation in the deltoid area returns

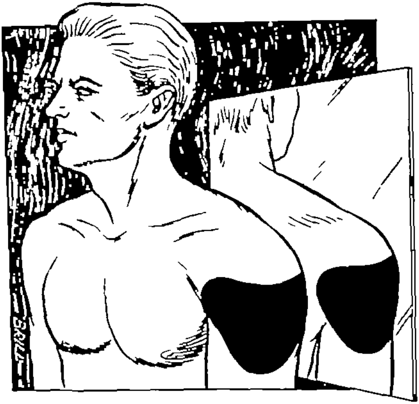


Fig 207 Area of hypoesthesia or sensory loss, following injury to circumflex nerve

rapidly to normalcy after reduction. In most instances in which loss of motor power is manifest after reduction recovery eventually takes place This however, may require many weeks and even months Only rarely does circumflex palsy become a permanent lesion

Fig. 208 Area of impaired sensation following lesions of the musculocutaneous nerve

Musculocutaneous Nerve Injuries Like the axillary nerve, the musculocutaneous nerve may be traumatized by the same abnormal mechanics of a dislocating head or it may be injured by direct pressure of the head which has been left in a dislocated position for a long period of time Clinically, the diagnosis is made by paralysis of the biceps brachii, the coracobrachialis and the brachialis muscles and by reduced sensibility along the lateral border of the forearm (Fig 208) Injury to the nerve is

the supraspinatus region (tears may be transverse or longitudinal) Eight of the 16 shoulders exhibited macroscopic tears of some degree in the fibrotendinous cuff Six of the 8 affected cuffs disclosed a defect in

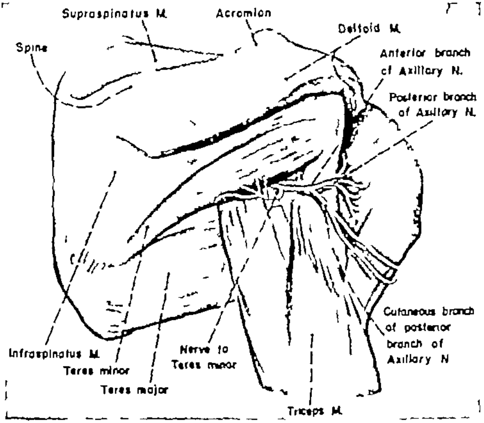


Fig 206 Course of axillary nerve as it leaves the quadrangular space The portion of the nerve proximal to the point of exit is the segment most apt to be injured in dislocations of the scapulohumeral joint.

the supraspinatus region In the light of this information it is reasonable to conclude that many of these cuffs sustained incom plete not demonstrable tears on the joint side of the cuff and that all sustained microscopic tears

10 Displacement of the biceps tendon from the bicipital sulcus

11 Fracture of the anterior long rim of the glenoid cavity

12 Severe stretching of the rotator muscles particularly the supraspinatus and the subscapularis muscles. This feature was constant in all the shoulders explored Its significance in the mind of the author has been underestimated in relation to development of recurrent lesions

Other Complications Exclusive of Fracture

Nerve Lesions

Axillary Circumflex Nerve Injuries. During dislocation, tremendous lateral pressure may be exerted on the brachial plexus in the axilla by the abducting and rotating humeral head Although any of the nerves may be involved the axillary nerve is injured most frequently It has been estimated that approximately 25 per cent of all dislocations are accompanied by axillary nerve trauma. The course and the position of the nerve in relation to the path of a dislocating humeral head renders it extremely vulner able (Fig 206) Fortunately stresses on the axillary nerve are rarely sufficient to cause complete ruptures but are often of sufficient severity to cause paralysis of the deltoid muscle In ruptures that have been explored the lesion occurred proximal to the exit of the nerve through the quadrangular space

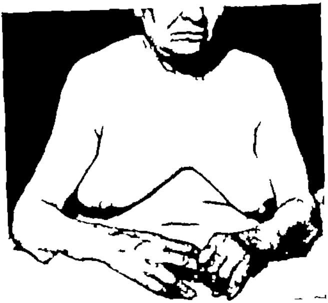


FIG 210 Subcoracoid dislocation of the right scapulohumeral joint. Normal rounded contour of the shoulder is lost the shoulder is flattened and the elbow projects from the side the arm appears lengthened when compared with the unaffected extremity

FIG 211 Subcoracoid dislocation Observe small fragment of bone sheared from the inferior portion of the glenoid brim.

opportunity to recognize early concomitant lesions. The characteristic features are

1 History of injury is always present. Occasionally it is trivial but in most cases it is violent in character

2 Pain and disability ensue. Any attempt to move the arm actively or passively accentuates the pain

3 Inspection discloses that the arm is maintained in a fixed position of slight abduction (25° to 30°) the long axis of the humerus being directed upward and inward The forearm is rotated internally and flexed The arm appears to be lengthened *The distance from the acromion to the external epicondyle on the injured side is greater than that on the normal side*

The patient tends to lean toward the affected side to allow the extremity to hang in a vertical position. The shoulder is flattened This is more noticeable if the patient is observed from behind while the acromion process is prominent. The axillary fold is fuller and at a lower level than that on the opposite side An abnormal prominence is discernible in the subcoracoid region (Fig 210)

4 Palpation of the area reveals a noticeable defect below the acromion and an absence of the globular mass made by the humeral head normally felt in this region However the humeral head can be palpated in its abnormal subcoracoid position rotation of the arm discloses the humeral head moving with the humeral shaft.

5 ROENTGENOGRAPHIC EXAMINATION is an essential part of the examination because *it not only definitely establishes the diagnosis* but demonstrates concomitant fractures of the humeral shaft or tuberosities which if present will alter the form of treatment (Fig 211)

While conducting the examination one never should fail to note the presence or the absence of areas of decreased sensitivity of the skin supplied by the sensory branch of the circumflex nerve One should examine the deltoid, the pectoralis major and the rotator muscles also the muscles of the arm and the forearm for motor power Notation

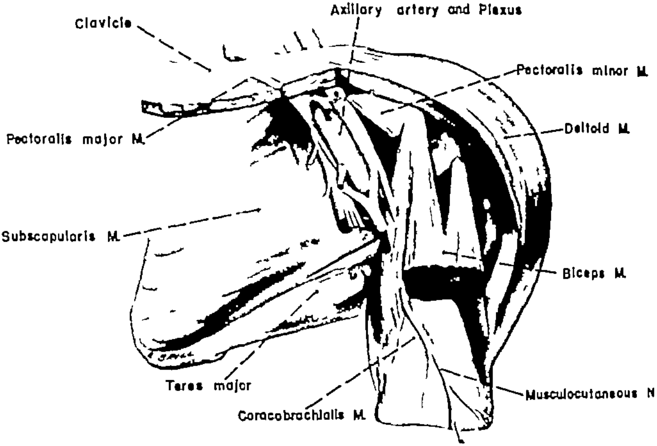


FIG 209 Course and vulnerable position of brachial plexus and musculocutaneous nerve which may be injured at the time of the dislocation or by pressure of the head of the humerus left in a dislocated position for a long period of time.

encountered only rarely It occurs however next in frequency to injuries of the circum flex nerve

Many other branches of the brachial plexus may be traumatized and inasmuch as the consequences of inadequately treated nerve lesions are so devastating it is man datory that at least a cursory neurologic examination be done in all cases of acute dislocation of the shoulder before reduction (Fig 209) A second evaluation of the brachial plexus should be done after reduc tion Only by such a procedure is one able to *recognize nerve lesions early and deter* mine definitely whether they complicated the dislocation or were the result of the reduction

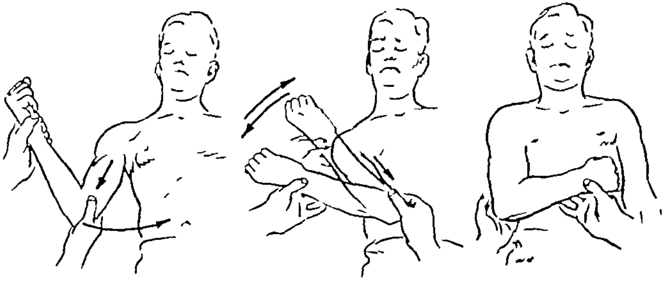
VASCULAR INJURIES Although rare in juries to the axillary artery or vein have been reported They may occur at the time of the injury or are produced by forceful maneuvers employed at reduction The author has seen one instance of severance of the axillary artery at the initial injury when the patient fell through the hatch of a ship and landed on the outstretched arm. Severance of the artery is made evident by obliteration of the radial pulse and a rapidly developing pulsating hematoma in the axilla or front of the shoulder Rupture of the vein is followed by a more slowly developing hematoma The extremity becomes markedly swollen and cyanotic. The vessels may be traumatized but not severed and aneurysm or arteriovenous fistula may develop

FRACTURES OF THE HUMERUS

(These are considered under Fracture Dislocations)

CLINICAL FEATURES OF ACUTE ANTERIOR DISLOCATION

Generally the diagnosis is so obvious that one often neglects to conduct a thorough ex amination of the part thereby forfeiting the



A B C

Fig 212 Reduction of dislocations of the scapulohumeral joint by steady traction on the humerus, first in the plane in which it lies in relation to the trunk (A) Traction is maintained while the arm is carried into a slightly adducted position this usually effects reduction Occasionally it may be necessary to rotate gently the arm externally and internally (B) After reduction, the arm is gently laid across the chest (C)

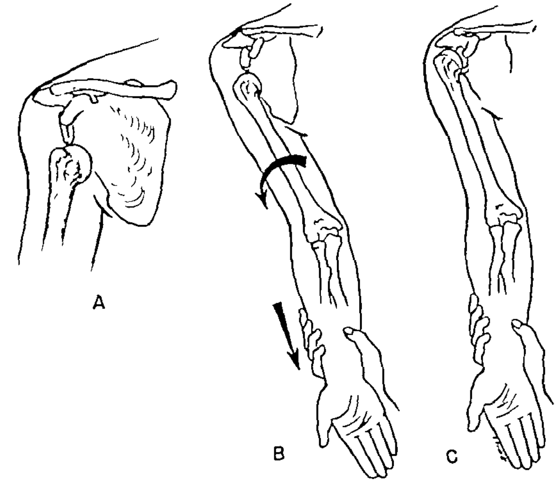


Fig 213 Reducing dislocations of the scapulohumeral joint as illustrated in Figure 212 except that traction is made with the arm extended instead of flexed.

of the vascular status of the arm never should be overlooked

Treatment The objectives to be achieved in the management of an acute uncomplicated inferior or anterior dislocation of the shoulder are (1) reduction without further trauma to the capsular element, the musculotendinous cuff the neurovascular structures and the bony components of the joint (2) maintenance of reduction to allow healing of the injured tissues and to prevent *redislocation and (3) restoration of normal* function Of necessity, treatment may be modified in the presence of concomitant complications or to prevent undesirable sequelae

One s choice of a method of reduction must be tempered by knowledge of the following clinical facts Most uncomplicated recent dislocations are reduced readily with minimum force when pain and muscle spasm are eliminated provided that the method of reduction is executed properly Difficulty in reduction is encountered only in the presence of an associated complication not recognizable by routine examination Reduction should be performed as soon after the dislocation has occurred as is possible because at this time disalignment of the bony components of the joint is maintained primarily by muscle spasm unless as has been pointed out previously complicating lesions exist.

Later the displacement is fixed by infiltration and organization of the soft tissues Elasticity of these structures is lost and now reduction can be effected only by more forceful maneuvers In the light of the pathology of acute dislocations it becomes apparent that any method of reduction which employs abduction and rotatory movements is likely to add further trauma to disrupted tissues or to produce new injuries Steady traction in the long axis of the humerus either in a neutral or slightly adducted position is the most essential maneuver of any method of reduction.

Choice of Anesthesia. Although many operators attempt reductions without a general anesthesia, it is the author's opinion that a general anesthesia should be used in every instance Complete muscular relaxation is essential to effect a reduction without force, and this cannot be obtained by the use of morphine or other opiates Pentothal Sodium is a very useful agent for this purpose

Traction on Adducted Humerus. This procedure will effect reduction in all uncomplicated early inferior and anterior dislocations *with minimum risk of added trauma.* It should take precedence over all other forms of reduction

The patient lies on his back and with the elbow flexed to a right angle, the operator makes firm, steady traction in the line of the adducted humerus Countertraction is provided by the patient s weight. If more is desired it may be attained by passing a folded sheet around the chest wall and pulling obliquely in the opposite direction. In many instances this maneuver alone will effect a reduction Slight rotatory motions, while traction is being maintained may be added if necessary (Fig *212*) Some surgeons make traction with the arm extended at the elbow (Fig *213*) However flexion of the elbow to a right angle relaxes the biceps tendon and the neurovascular bundle thereby eliminating the risk of injury to these structures.

Kocher s Maneuver This procedure was designed primarily for subcoracoid dislocations the various steps cause the humeral head to retrace its path into its normal anatomic position When the operation is performed gently no harm ensues However, if improperly executed severe damage to the brachial plexus and the humerus may result At all times one must be cognizant of the fact that Kocher s manipulation is based on a series of rotatory movements of the humeral head also that great force can be exerted on the upper end of the humerus and the glenohumeral soft tissue elements by using the arm as a lever Fractures of the humeral shaft massive avulsions of the rotator cuff and injury to the circumflex

wrist with the left Firm, steady traction is made in the line of the long axis of the humerus or preferably in slight adduction Following this stretching phase the three Kocher steps are carried out (Fig 214)

EXTERNAL ROTATION Traction being maintained on the humerus, the forearm is moved outward gently and slowly to the limits of external rotation The forearm now lies in a position of 70° to 80° external rotation Such a maneuver stretches the subscapularis muscle and allows the head to move so it impinges against the anterior margin of the glenoid fossa

FORWARD ADDUCTION Traction and external rotation being maintained the elbow is moved forward slowly and steadily to a point near the midline of the body By this procedure the head is levered over the glenoid brim As a rule reduction occurs during the execution of this step

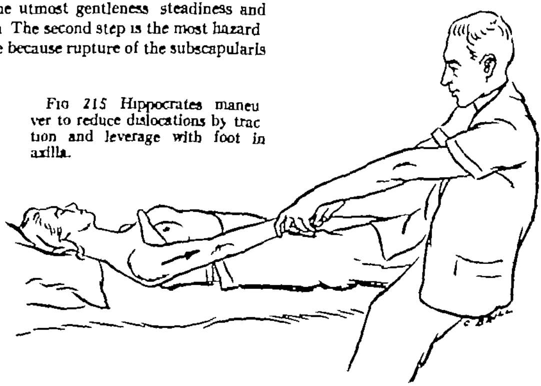
INTERNAL ROTATION While holding the elbow close to the midline, the arm is rotated internally by moving the forearm across the chest so that the hand falls over the opposite shoulder This last step in the manipulation places the head in its normal anatomic position

It cannot be overemphasized that all phases of this method must be exercised with the utmost gentleness steadiness and caution The second step is the most hazardous one because rupture of the subscapularis tendon or fracture of the shaft may occur readily *during its execution Should the first* attempt fail, another may be attempted, but a third attempt is contraindicated, because some unrecognized complication undoubtedly exists, and surgical intervention is now justifiable as a safer approach to the problem

Traction and Leverage with Foot in the Axilla (Hippocrates Method) This method is mentioned only to condemn it The amount of traction and leverage that are used in its execution make it a formidable procedure The number of catastrophies following its employment surpasses those of all the other methods combined Nerve injuries are particularly likely to occur Moreover, the procedure never is indicated either as a routine method or in isolated cases, because simple traction on the adducted humerus or the Kocher manipulation are capable of reducing all uncomplicated dislocations

The patient lies on his back for a right sided dislocation the operator places the bared right foot into the axilla close to the ribs He grasps the patient's wrist in both

FIG 215 Hippocrates maneuver to reduce dislocations by traction and leverage with foot in axilla.



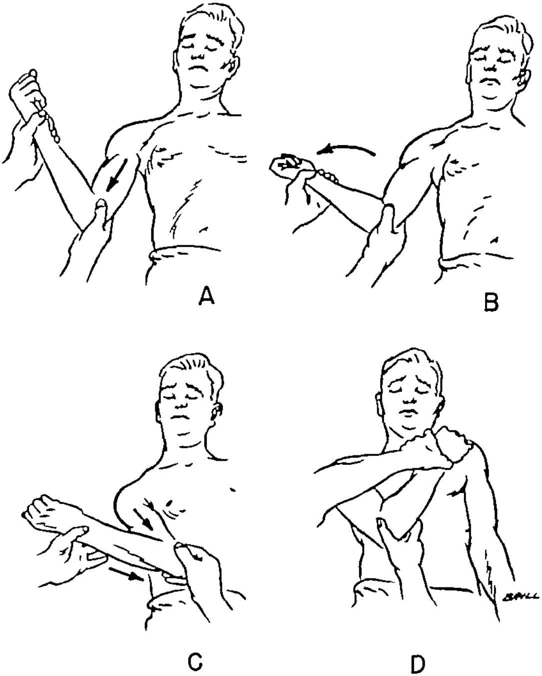


FIG 214 Kocher s maneuvers to reduce dislocations of the scapulohumeral joint. (A) Preliminary stretching in the line of the long axis of the shaft of humerus in slight abduction. (B) The arm is externally rotated (C) the elbow is moved forward to a point near the midline of the trunk. (D) Finally the arm is internally rotated so that hand falls over the opposite shoulder

nerve are frequent catastrophies resulting from the injudicious use of this method

One is justified to risk the hazards of the Kocher method only when traction on the adducted humerus method has failed or in late dislocations when soft tissue organiza tion and contracture demand the use of more forceful means to dislodge the humeral head and to replace it in the glenoid fossa

Before an extremity is put through the various Kocher steps there should be a preliminary stretching maneuver to bring the upward displaced head to the inferior margin of the glenoid cavity The patient is placed on his back with the elbow flexed for a right-sided dislocation the operator grasps the lower end of the humerus above the epicondyles with his right hand and the

referable to the shoulder joint have not been emphasized sufficiently

The following clinical facts should govern the management of acute dislocations Although this lesion is encountered more frequently in muscular individuals under 30, 'frozen shoulders' are rarely observed before the age of 30 and usually occur after middle life Recurrences are common complications before 30 years, but they are rare after 45 years of age Recurrent dislocation is, in a true sense, self limiting in nature The author has three cases under observation aged 52, 57 and 61 years respectively All have had frequent recurrences during youth but without any form of treatment none has had a dislocation after his forty fifth year

It is obvious that some process is at work which over the course of many years, eventually stabilizes the glenohumeral joint. In the investigation on lesions of the shoulder joint it has been noted that after the third decade there is macroscopic and microscopic evidence that in the capsular tissues and the musculotendinous cuff progressive degenerative changes characterized by fibrosis thickening and loss of elasticity occur normally This observation is sustained further by a study of 800 cases in various age groups which disclosed a gradual decrease in the range of external rotation in each subsequent decade (Fig 217)

One must conclude therefore that the afore mentioned process, which ultimately is responsible for restriction of external rotation also is the agent which restores stability Nature's method to cure the malady is by restricting external rotation The surgeon unknowingly accomplishes the same objective by numerous ingenious operative procedures.

Too much emphasis has been placed on trauma sustained by the labrum glenoidale, the humeral head and the fibrous capsule in relation to the pathogenesis of recurrent lesions. On the other hand there has not been enough emphasis on the trauma inflicted upon the muscular apparatus, particularly the rotator muscles, of the glenohumeral joint It was noted in the pathology of acute dislocations that the most constant lesion was stretching and at times tearing of the short rotator muscles It is the writer's opinion that such trauma initiates a neuromuscular state characterized by loss of tonicity and efficiency similar to that associated with stretch paralysis of muscles When such a state persists the stabilizing effect of the rotator cuff is inadequate, and if the muscles are caught off guard or submitted to sudden severe strain while the arm is in some position of abduction and external rotation, recurrent dislocations ensue

Frequency of recurrence is not dependent upon the degree of capsular relaxation, or the presence and the size of a defect in the humeral head or the severity of a "Bankartian lesion" (torn and detached labrum), but to the degree of inefficiency and loss of muscle tone of the short rotator muscles This postulate is supported by observations made on shoulders obtained postmortem from individuals who prior to death had given no history of traumatic or recurrent dislocation Lesions observed in the shoulders of these individuals were similar to those described by Bankart and others

This fact leads one to conclude that the pathology noted by these observers is not the causative factor but only concomitant lesions of recurrent dislocation They result from normal wear and tear and senescence, or they may be produced by trauma (see Chap 3) If the above concept is accepted it becomes mandatory that rest be an essential prerequisite for the restoration of normal muscular action and the efficiency of the short rotator group

In accordance with the above reasoning one must modify the postreduction management to fit the individual case As a rule in the treatment of young muscular individuals, one should be concerned primarily with the prevention of recurrences since stiffness due to prolonged fixation rarely occurs in the younger age periods. Immediate redislocation during the healing phase will not

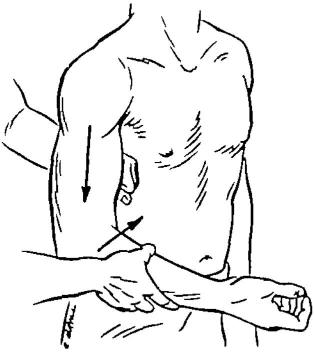


FIG 216 Nicola's maneuver, by making downward traction on the arm and by using the fist in the axilla as a fulcrum to lever the head over the glenoid brim

hands and makes slow steady traction in slight adduction The foot is used as a fulcrum to lever the head over the glenoid brim. Slight outward rotation of the shaft may be necessary at times to complete the reduction (Fig. 215)

Post Reduction Management. There is still considerable disagreement as to the optimum position to maintain reduction whether or not the arm should be immobilized and when mobilization should begin Some observers advocate fixation in abduction others in a sling or some other comparable apparatus Some advocate fixation of the extremity for one week others for eight It is obvious that this diversity of opinions is based on a lack of comprehension of the detailed pathology of acute dislocations and of the factors responsible for crippling sequelae and recurrences. More over, certain accepted clinical observations

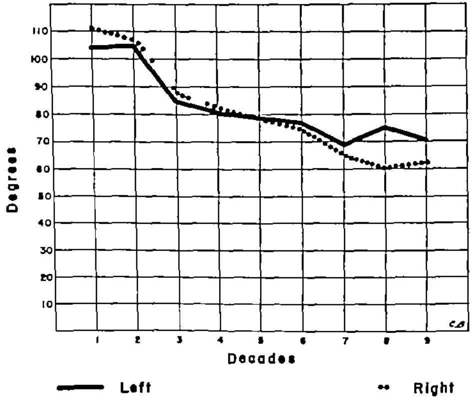


FIG 217 Graph showing gradual decrease in range of external rotation with advancing age Study was made on 800 individuals 100 in each decade from the first to the eighth. Only individuals who never suffered a dislocation or who never had severe injuries to the shoulder joints were selected for this investigation.

which the heads are near their anatomic positions and offer greater resistance to reduction, indicating less soft tissue disruption

Gravity free stooping exercises of the extremity several times daily are started immediately (Fig 238) Care must be taken to move the limb within the painless arcs of motion—never to go beyond Thus, healing tissues are not subjected to unnecessary deleterious strains. For the first 2 weeks abduction against gravity is restricted to 45° Free usage of the arm within this safe range *is encouraged Within the following 2 weeks* abduction is increased gradually to the horizontal position All restricting apparatus is discarded after the fourth week, and gradual progressive return to complete function is *allowed Optimum functional results should* be achieved in from 8 to 10 weeks.

COMPLICATIONS OF DISLOCATION OF THE SHOULDER

In general, the extent and the frequency of bone, capsular and nerve injuries associated with dislocation have not been fully appreciated Detection of such lesions is a *simple matter, provided that the examiner* is aware of their possible existence and looks for them Careful evaluation of the extremity by clinical methods and radiography both before and after reduction is essential in order to detect concomitant lesions As previously stated their existence modifies the treatment of the dislocation

The more common complications are

1 Fracture of humeral head (All types and combinations may occur)

2 Fracture of the glenoid rim

3 Rupture of the rotator cuff (The extent varies from incomplete tears to complete avulsion of the cuff)

4 Dislocation of the biceps tendon

5 Brachial plexus injury (The circumflex nerve is injured most frequently)

6 Vascular injuries.

The above lesions are considered in detail in Chapters 4 8 and 9

OPEN REDUCTION FOR INITIAL DISLOCATION

Conservative methods may fail to reduce what clinically appears to be an uncomplicated dislocation Forceful maneuvers should not be employed when failure of reduction occurs Less damage is inflicted if the joint is explored and inspected and if the lesion interfering with reduction is identified If no fracture complicates the dislocation, the most common causes for failure of reduction are interposition of portion of the cuff or the inferior capsule between the *glenoid fossa and the head of the humerus,* or posterior displacement of the biceps tendon

McLaughlin's superior approach (see Chap 11) is employed It affords an excellent exposure of the entire subacromial region and the interior of the joint cavity with minimum risk to the axillary nerve. After the lesion responsible for interference is eliminated reduction is effected by gentle traction on the adducted humeral shaft. If necessary slight rotatory motions may be added Longitudinal rents in the cuff are closed by interrupted side-to-side sutures *Transverse ruptures are repaired in the* manner described in Chapter 4 Avulsion of the biceps tendon means disruption of the tendon tendon sheath gliding mechanism and is likely to initiate a disabling tenosynovitis In order to avoid such a complication, the author prefers to release the tendon at its insertion into the superior brim of the glenoid cavity and transplant it into the coracoid process (see Bicipital Tenosynovitis) The frequency of tenosynovitis of the biceps tendon following dislocation and fractures of the humeral head in the region of the intertubercular sulcus justifies this procedure

If the head was forced out of a rent created by stripping of the inferior capsule from the neck of the humerus, no repair is necessary because spontaneous healing occurs readily in this region

Postoperative management is that of

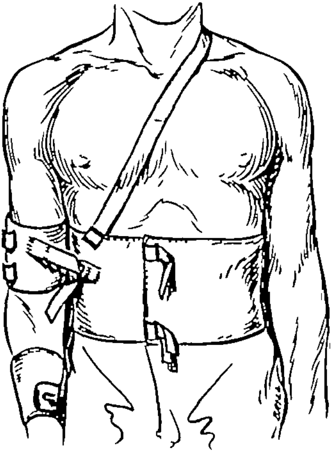


FIG 218 Nicola s apparatus used to immobilize the arm following acute dislocations in young individuals. It limits abduction and external rotation.

occur unless the extremity is hyperextended or abducted and rotated externally against gravity Late recurrences occur with failure of the rotator muscles to return to normalcy The best results in this group are obtained by immobilizing the extremity to the side by apparatus as described by Nicola (Fig 218)

It restricts elevation abduction and all rotatory motions yet allows a few degrees of forward and backward motion sufficient to promote absorption of debris within the traumatized joint Motion at the elbow the wrist and the hand should be encouraged Fixation is maintained for 8 weeks then a program of graduated motions is prescribed within the limits of pain and tolerance of the patient. At the beginning motion should be performed in a stooped position every hour during the day for from 5 to 10 minutes Later, as the range of motion and muscular power increases, wall-crawling and pulley exercises are added

Free use of the arm is permissible within the limits of pain and fatigue. Physical therapy in the form of radiant heat and gentle massage of the entire shoulder girdle is a valuable adjunct, but the patient must be convinced that this form of therapy has no curative powers and that active motion is the key to rapid and normal restoration of shoulder function Resumption of all activities and optimum function are attained within the next 4 weeks Under the above regimen, sufficient time is allowed for complete return of muscle power, and tone and all capsular tissues are permitted to heal under minimum stress Rehabilitation when started proceeds rapidly until complete function is attained

The older age groups particularly the very aged present totally different problems. Recurrence of a dislocation rarely takes place on the other hand stiffness must be avoided in the later decenniums. Clinical experience discloses that frozen shoulder is a frequent disabling complication following all traumatic lesions about the shoulder joint The best treatment for this lesion is prevention which can be accomplished by early mobilization within the tolerance of pain

Immediately after reduction a sling or collar and-cuff is applied (Fig 237) This simple fixation suffices to maintain abduction and external rotation within safe limits thereby preventing redislocation. Although early mobilization and rapid restoration of function are the aims of the surgeon the rapidity with which they are attained must be governed by his evaluation of the case. Initial dislocations in which the heads are displaced at a great distance from the glenoid fossa and are reduced with relative ease indicate extensive soft tissue and capsular damage Protection of these shoulders should be longer and restoration to full activity should be slower than those in

FIG 219 (*Left*) Characteristic features of the normal glenohumeral articulation with the head of the humerus rotated externally Note the prominent lateral border of the head formed by the greater tuberosity, the lesser tuberosity is medial and parallel to it, while the intertubercular sulcus is visualized between the two The glenoid fossa casts a crescent shadow over the medial articular surface of the head The rounded articular surface of the head covers the inferior region of the glenoid fossa. (*Right*) Characteristic features with the humerus rotated internally The greater tuberosity is barely distinguishable, while the lesser appears to be in the glenoid cavity The inferior portion of the glenoid fossa is covered by the tuberosities. Note that the rounded articular surface of the head is directed upward and outward.

In internal rotation the tuberosities are seen on the medial side of the humeral shaft In fact, the lesser tuberosity appears to be in the glenoid cavity, and the greater tuberosity is barely distinguishable, the rounded articular surface of the head being now directed upward and outward At the same time the glenoid fossa casts a crescent shadow over the tuberosities (Fig 219, *right*)

In anteroposterior views of a posterior dislocation the afore mentioned normal features are greatly distorted. The humeral shaft lies in full internal rotation However, the lateral margin of the head is formed by the lesser tuberosity while the greater tuberosity medial to it is barely visible The inferior region of the glenoid fossa is now exposed and no longer covered by the spherical articular surface, as in normal external rotation and by the tuberosities in normal internal rotation (Fig 220)

Lateral views obtained by placing the cassette on the abducted shoulder and directing the rays into the axilla are more reliable than those directing the rays through the thorax with the cassette on the lateral aspect of the dislocated shoulder

Under general anesthesia reduction is effected readily by gentle steady traction on the arm with the elbow flexed in the long axis of the humerus When the head reaches the brim of the glenoid fossa, gentle adduction and internal rotation of the arm complete the reduction Pressure on the head from behind may facilitate the reduction

simple, uncomplicated dislocation reduced by conservative methods but should be tempered by the surgeon's knowledge of the extent and the severity of the soft tissue injuries observed at operation

LUXATIO ERECTA

Reduction of this lesion is effected readily by traction on the arm directed upward and slightly outward Countertraction, if desired, may be provided by a sheet across the supraclavicular region pulling downward Reduction is indicated by an audible snap, as the head glides over the rim and engages the glenoid fossa. The arm is then brought gently to the side Postreduction treatment is similar to that of subcoracoid dislocation

ACUTE TRAUMATIC POSTERIOR DISLOCATION

This type of dislocation is extremely rare and frequently it is unrecognized Depending upon the location of the humeral head it is classified either as subacromial or subspinous. Usually its mechanism of production is one of forceful dorsal flexion with the arm rotated internally Cases have been reported in which the head was displaced backward by a direct force on the anterior aspect of the shoulder joint Epileptic convulsions is a frequent cause of posterior dislocation The author has seen one case following electric shock therapy

Most writers note that the head is forced through a rent in the posterior capsule In the literature however this conception lacks confirmation of acute cases explored with the head in a posterior position Codman noted the findings of one case of an old unreduced subspinous dislocation in which he recorded that none of the short rotators was ruptured Robertson and Stark observed after operating on three cases of recurrent posterior dislocation that in every case the capsule was redundant and lax.

Like Rowe and Yee, Hindenach failed to find a detached labrum glenoidale Rowe and Yee noted in two cases that the capsule had been stripped from the neck of the scapula. All the above recurrent lesions followed initial traumatic dislocations It is logical to assume from the observations made in anterior dislocations that the humeral head in posterior lesions may be forced through a rent in the musculotendinous cuff, or they may strip the labrum, the capsule and the rotator muscles off the posterior surface of the neck of the scapula and lie beneath them in an intracapsular position Regardless of whether the head is intracapsular or extracapsular, it is obvious that the soft tissues are stretched or torn severely Damage of varying severity may also be inflicted upon the head and the glenoid rim

Although the diagnosis is made readily, the great amount of swelling around the shoulder joint may confuse the clinical picture The anterior region of the shoulder is flattened while the acromion and the coracoid processes are prominent A globular mass is palpable posteriorly which rotates with the shaft. The arm is held in adduction occasionally depending on the position of the head as in a subspinous position it may be slightly abducted and forward. All motions are painful

Roentgenographic examination in the anteroposterior view may fail to demonstrate the lesion but lateral views depict clearly the relation of the head to the glenoid fossa Failure to recognize the lesion in anteroposterior views can be attributed chiefly to unfamiliarity with the appearance of the glenohumeral joint in various degrees of rotation

In external rotation the greater tuberosity forms the prominent lateral border of the humeral head the lesser tuberosity being medial and parallel with it The intertubercular sulcus and the bicipital groove are visualized clearly between the two The medial border of the head is formed by its smooth hemispherical articular surface over which the superimposed glenoid fossa casts a crescent shadow The rounded articular surface of the head covers the inferior region of the glenoid fossa (Fig 219 *left*)

better results than the open procedures Cases which are irreducible by the ordinary closed methods properly executed usually have existed for a long time, and profound secondary changes of the affected tissues have taken place

Pathology

In addition to the tissue damage recorded in the pathology of *anterior dislocation*, advanced secondary changes characterized by tissue infiltration and organization are found in the late lesions Depending upon the duration of the lesion, there are varying degrees of fibrosis, contracture and shortening of all involved tissues particularly the musculotendinous cuff and the fibrous capsule with scar tissue formation firmly fixing the humeral head in its unnatural site to the neighboring structures The long adductors *and the internal rotators* (pectoralis major, teres major and latissmus dorsi muscles) *also became fibrotic and shortened* Tough, inelastic scar tissue fills the synovial cavity, obliterating it completely In very late cases the articulating cartilage of the glenoid fossa and the humeral head undergoes fibrillation, thinning and, finally, erosion and complete disintegration Loose bony fragments, if present become embedded in fibrous tissue. Profound demineralization and bone atrophy may be discernible in the glenoid, the humeral head and the shaft. In very old cases bony proliferation appears on the glenoid rim and at the point of contact of the head against the scapula The biceps tendon not infrequently is traumatized severely It may be severed completely its distal end having reattached itself to the *humeral shaft below the lesser tuberosity* In two instances it was displaced posteriorly, *thereby preventing reduction*

It is apparent that success of ordinary *closed methods* depends entirely on the extent of the initial trauma and the degree of superimposed secondary changes

Course of Untreated Cases

Although some observers have recorded cases in which pain was insignificant and functional capacity of the shoulder fair, usually this lesion is associated with considerable pain and pronounced disability In most instances, pain is not lessened, nor is function improved with time In some late cases (if pain is not severe and the functional adaptation is fair) no interference other than physical therapy is indicated to *improve the muscular tone and the range of* motion of the extremity This is particularly true *in elderly individuals However* if pain is pronounced and the functional adaptation is poor, attempts at reduction are justifiable, especially in younger individuals in whom no other contraindications exist

Choice of Treatment

To accept the dislocation and to strive for as much function as possible by physical therapy is justifiable in *elderly individuals* in whom pain is not a prominent factor, and *also in patients for whom manipulative* attempts at reduction have failed and operative intervention is contraindicated

Closed manipulative methods should be attempted in dislocations under 12 weeks' duration Not infrequently physical examination discloses marked contracture and shortening of the adductors and the internal rotators In such instances, preliminary skeletal traction through the olecranon in the line of the axis of the humerus may facilitate the reduction

Reduction by open methods is indicated in *all dislocations over three months* duration and when reduction has failed by the *closed procedures*

Arthrodesis of the glenohumeral joint *though a radical procedure* may be necessary in the presence of advanced disintegration of the articulating surfaces of the glenoid and the humeral head It is preferable in younger individuals when because of severe degenerative changes in the affected tissues it is obvious that simple replacement of the humeral head will not result in a very serviceable shoulder joint. Consideration of the earning capacity of

FIG 220 Posterior dislocation Note the loss of outline of the greater tuberosity The lower portion of glenoid cavity is exposed and no longer covered by the spherical articular surface of the head in normal external rotation and the tuberosities in internal rotation.

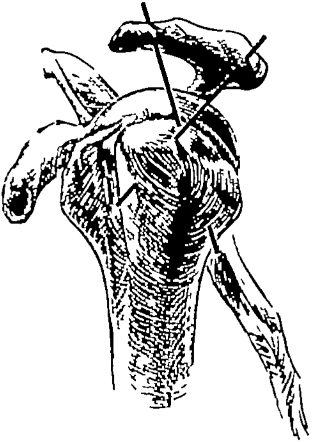


FIG 221 Method to maintain position following reduction of posterior dislocations which tend to recur (Wilson and McKeever)

As a rule the latter maneuvers are not necessary Postreduction treatment is the same as for anterior dislocations

Most posterior dislocations are followed by no disturbing sequelae if reduced properly and early but recurrent dislocations occasionally ensue At times the reduction after the initial trauma is difficult to maintain. J C Wilson and F M McKeever have devised an ingenious operation to stabilize the glenohumeral joint after reduction (Fig 221) The acromion and the head of the humerus are fixed by two wires crossing one another The wires are drilled through the top of the acromion and through the head They are left protruding from the skin over the acromion and are removed in three weeks Wilson and McKeever advocate this type of fixation also for old posterior dislocations after reduction is attained by surgical intervention.

OLD DISLOCATIONS

Unreduced dislocations of the shoulder joint tax the skill of the most experienced and skillful surgeons. Adequate management is influenced by many factors such as the age of the patient, the severity of the symptoms the degree of disability and the duration of the lesion Treatment based on faulty evaluation of these factors is doomed to failure and may be responsible for irreversible damage to the brachial plexus, the axillary artery and vein the musculotendinous cuff and the bony components of the glenohumeral joint. Prognosis should be guarded in all old dislocations. In general, it is better in the early than in the late cases and successful closed methods give

head ensue Such a complication will cause a stiff and painful shoulder in spite of good reduction Posterior displacement of the biceps tendon may be a formidable obstacle to reduction In such instances, the tendon is divided, and its proximal end is passed through the humeral head and reattached to the distal end, as in a Nicola procedure

Reduction having been accomplished, attention is directed toward repairing the capsular defect The divided tendons (subscapularis and pectoralis major) are resutured, and, if an opening in the capsule remains, some type of repair must be attempted to prevent subluxation or dislocation

Maintenance of the reduction may prove to be difficult A Nicola operation may ensure stability of the joint Cubbins has utilized the coracohumeral ligament for this purpose The ligament is cut close to its coracoid attachment and freed down to the humeral insertion The proximal free end is then passed through a drill hole in the acromion and anchored to the periosteum on its superior surface The transposed structure then functions as a suspensory ligament of the humeral head

Neviaser maintains reduction with a vitallium transfixion screw passing through the head into the glenoid cavity The screw is removed after 3 or 4 weeks (Fig *222*)

The method of stabilization for recurrent posterior dislocations by Wilson and McKeever appeals to the writer as a method worthy of trial in maintaining reduction after it is effected in old dislocations These workers transfix the humeral head and the acromion with cruciate wires the ends of which are left protruding from the skin over the superior surface of the acromion They are removed after 3 weeks

In cases in which no internal fixation is used to stabilize the joint postoperative immobilization with plaster or splint is necessary The most stable position of the arm is from 60 to 80 elevation midway between the coronal and the sagittal planes. Fixation is continued from 4 to 6 weeks and

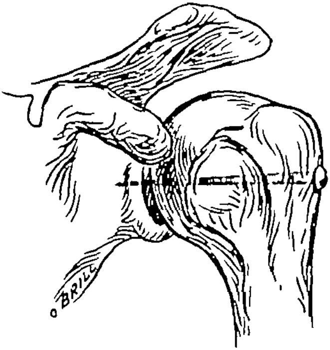


FIG *222* Neviaser's method of maintaining normal position after reduction of old dislocations of the scapulohumeral joint.

followed by intense physical therapy Graduated active exercises (first gravity free and later against gravity) are the most important features of this phase of the treatment.

The result may be considered satisfactory if the patient is free of pain and can abduct the glenohumeral joint 60° with good muscle power Weak abduction in some cases may be the result of axillary nerve injury at the time of the initial trauma or it may result from pressure of the dislocated humeral head on the nerve, or injury at the time of operation.

RECURRENT DISLOCATION OF THE GLENOHUMERAL JOINT

The lamentably high percentage of failures of popular stabilizing procedures for recurrent dislocation has been in recent years a stimulus to investigate further the pathogenesis and the management of this lesion. Hitherto the profession at large was inclined to accept as final, observations made without further investigation of the problem Also there has been a tendency to

patients in the younger age group should influence the surgeon's ultimate choice A painless arthrodesed glenohumeral joint is by far more serviceable than a painful joint with from 30° to 60° of abduction

Resection of the humeral head occasionally must be performed If extensive stripping of the soft tissues is necessary to mobilize the head, aseptic necrosis of the head of the humerus invariably ensues, resulting in a stiff and painful shoulder Resection of the head in such instances is justifiable This may or may not be followed by arthrodesis depending upon the age and the activity of the patient A flail shoulder joint, while painless, is not very serviceable but it may suffice for aged individuals.

Closed Methods

All manipulative maneuvers used in old dislocations even in the hands of the skillful, are dangerous and may produce extensive damage to the brachial plexus and the axillary artery, or they may fracture the humerus. The operator must be cognizant of these potential hazards and be ready to accept such complications In view of the *existing pathology of necessity all maneuvers* must employ considerable force the extent of which must be tempered by the skill and the experience of the surgeon

Complete relaxation is essential and is best attained by general anesthesia Before definitive maneuvers are employed to effect reduction the humeral head is mobilized by steady traction on the arm with the elbow flexed The shaft is then rotated inwardly and outwardly slowly and forcefully thereby freeing the head in its bed from all adhesions Next, while traction is maintained the arm is abducted slowly and rotated externally Such maneuvers overcome contracture and shortening of the long and the short adductors and the internal rotators particularly the pectoralis major and the subscapularis muscles

Following the foregoing preliminary maneuvers replacement of the humeral head is attempted by the Kocher method Failure to attain a reduction justifies another trial by the same or a different operator, but repeated attempts at reduction are condemned Every attempt is accompanied by extensive soft tissue damage and increases the risk of severe complications

Failure to effect a reduction leaves the operator one of two choices, either to accept the disability and try to regain the maximum function possible by physical measures or, at a later date, to resort to open methods

Open Methods

Bennet emphasizes several pertinent points in the technic of open procedures which facilitate repositioning of the humeral head adequate exposure of the area, cleaning the glenoid cavity of all scar tissue, and severance of the subscapularis tendon

The author has found that the best exposure is afforded by the incision of Cubbins Callahan and Scuderi (Fig 337) By careful dissection, the joint capsule and the humeral head in their abnormal position are identified Upon external rotation of the humerus, the subscapularis muscle is visu*alized and cut about one half an inch from* its insertion into the lesser tuberosity Retraction of the muscle medially provides adequate exposure of the glenoid fossa which is now cleaned of all accessible scar tissue Care must be taken not to injure the axillary nerve when the subscapularis tendon is divided This mishap can occur readily and occasionally does.

In most instances, severance of the subscapularis muscle permits sufficient mobilization of the head to effect a reduction. Occasionally it may be necessary to divide part or all of the insertion of the pectoralis major As a rule use of the Kocher method permits the head to be restored with comparative ease to its normal position in the glenoid fossa If necessary a bone skid may be used to lever the head into position. Extensive stripping of the capsular attachments from the humeral head and neck must be avoided lest asceptic necrosis of the

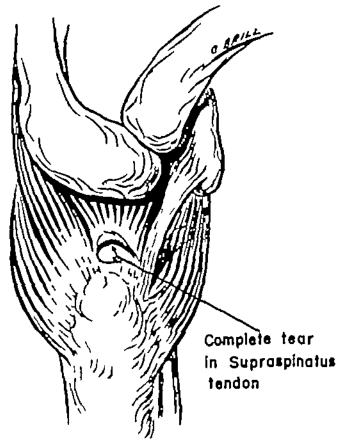


FIG 224 Small complete supraspinatus tear found in 2 of 56 cases of recurrent dislocation explored.

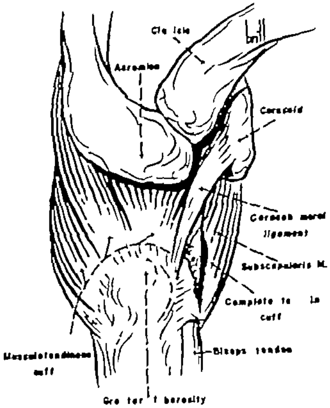


FIG 225 Small complete tear found in 3 of 56 cases of recurrent dislocations explored.

posterior views with the humerus in 50° to 80° of internal rotation It is apparent that difficulty in demonstrating the lesion is responsible for the wide discrepancies recorded in the literature Adams reports an *incidence of 82 per cent.*

Hill and Sacks describe the defect as a flattening or depression of the posterolateral region of the articulating surface of the humeral head Roentgenographically, it is visualized as a depression in the upper and outer quadrant of the spherical head of the humerus (Fig. 223) Frequently a line of increased density is observed extending distally from the top of the humerus along the mesial margin of the defect and parallel with the humeral shaft.

Those who are convinced that the above defects in the humeral head are capable of producing dislocation also believe that the frequency of the lesion depends upon the size of the lesion. As the defect increases in size the tendency to dislocation becomes greater

Both lesions, detachment of the labrum glenoidale and defects in the humeral head may exist in the same shoulder or independently In a comprehensive study, Adams recorded detachment of the labrum from the glenoid rim (Bankartian lesion) in *87 per cent of the 79 shoulders explored* 13 per cent disclosed normal attachment of the labrum. Of 68 cases studied, 56 (82 per cent) disclosed bone defects in the humeral head He noted that when a labral defect was not discernible, the head of the humerus disclosed a bone defect in its posterolateral region

Pathologic Observations. The following pathologic observations were made in 56 recurrent dislocating shoulders of 56 individuals *There were 55 males and 1 female,* their ages ranging from 19 to 33 years The woman was 33 years old In all instances the initial lesion resulted from some form of violent injury However the author has seen 4 cases not included in this study in

Fig 223 Defect in the upper and outer aspect of the head of the humerus of a patient with recurrent dislocations.

designate some local abnormality in the glenohumeral joint as the causative factor of the lesion

When the pathology of recurrent dislocation is considered most workers fail to evaluate the glenohumeral joint in its entirety restricting themselves to some local irregularity of the labrum glenoidale the humeral head or the fibrous capsule We are taught that the stability of the glenohumeral joint is directly dependent upon the surrounding intricate muscular apparatus that motivates the joint Yet when a state of instability exists local defects in other components of the joint are credited as causative agents

Pathology

Numerous theories have been offered as the underlying causes for recurrent dislocation Bankart stoutly defends his belief that the pathology in all instances is either a detachment of the labrum from the anterior glenoid brim or a tearing away of the capsule from the labrum He goes so far as to express the view that the recurrent lesion is an entirely different entity from the ordinary acute traumatic dislocation The former, according to his view, is invariably an anterior dislocation which tends to recur because the fibrocartilaginous labrum fails to reattach itself to the glenoid margin The latter is an inferior dislocation, the head being forced through a rent in the fibrous capsule which heals readily to bone, thereby preventing recurrences These features of the morbid anatomy of recurrent dislocation were recorded by Broca and Hartmann as far back as 1890 These observers also noted a defect on the posterior aspect of the humeral head which they believed facilitated intracapsular subluxation of the head of the humerus Many other workers described the above labral and capsular defects and concentrated their efforts in repairing them in order to effect a cure of the lesion

Since the first report on defects of the humeral head in relation to recurrent dislocation by Broca and Hartmann other investigators have confirmed this abnormality and stated that it plays a major role in the production of recurrences (Fowler, Schultze Pilz Holland, Sacks and Adams) According to Adams this causative factor has not been generally accepted because of the difficulties in visualizing the defect by routine anteroposterior roentgenograms, and exposing the lesion at operation by the anterior incision commonly employed.

Hill and Sacks are of the opinion that the defect is a compression fracture of the spongy bone in the posterolateral region of the head of the humerus sustained by forceful impact of this area against the glenoid rim at the time of the initial dislocation. They contend that the lesion is only demonstrable roentgenographically when anteroposterior views are taken with the arm in internal rotation or in tangential projections. Adams demonstrates clearly that defects are most often demonstrable in antero-

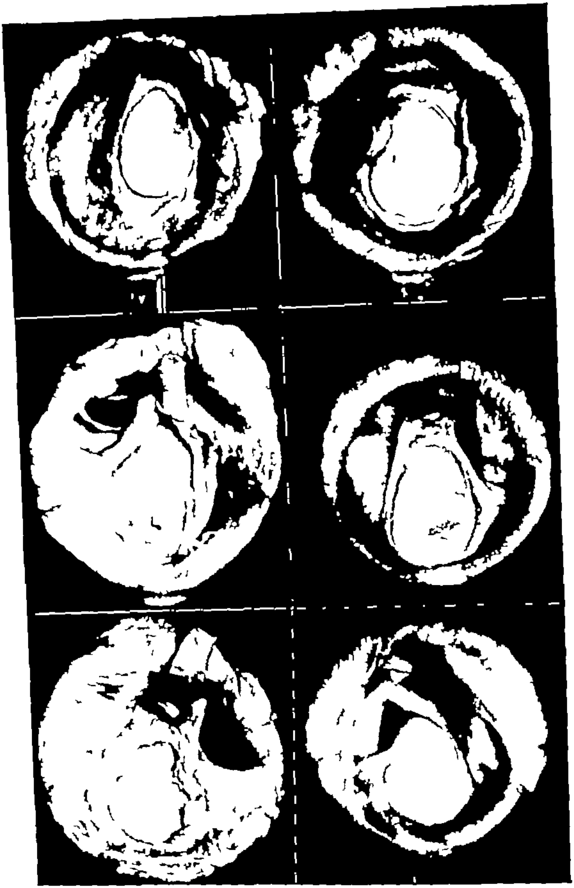


FIG 227 Types of subscapularis recesses found in 88 6 per cent of the shoulders studied in the investigation on variational anatomy and degenerative lesions of the shoulder joint. Note that in the anterior aspect of the joint the fibrous capsule is not continuous with the labrum but is projected mesially to the subcoracoid region and then reflected onto the neck of the scapula to blend with the labrum

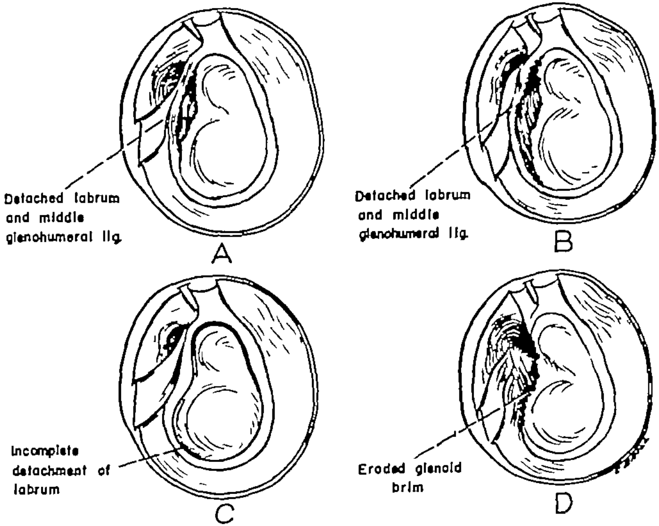


FIG 226 Varying degrees of labral detachment found in series of recurrent dislocations investigated surgically Eighty five per cent exhibited lesions (A, B and D) In 15 per cent, the labrum and capsule were intact (C)

which the initial dislocation resulted from trivial injuries Two others also excluded from this series recalled no trauma whatsoever The lesion was bilateral in 2 of the 6 cases

Musculotendinous Cuff An observation of considerable significance was the pronounced laxity of the cuff It appeared as if the short rotators were unduly stretched and lacked normal tonicity In 2 instances (3 5 per cent) small tears not over 1 cm wide were demonstrable in the supraspinatous region of the cuff The margins of the defects were smooth indicating that the lesions were not recent. Three shoulders (5.3 per cent) disclosed partial detachment of the inferior portion of the subscapularis tendon at its insertion into the lesser tuberosity (Figs 224 and 225)

Labrum Glenoidale and Fibrous Capsule. Some degree of detachment was discernible in 48 cases (85 per cent) The detachment was invariably from the anterior or antero-inferior portion of the glenoid rim. All degrees of detachment were noted varying from 1 or 2 cm. in length to complete detachment of the entire anterior half of the fibrocartilaginous ring In most instances the capsule and the periosteum, together with the labrum were stripped for varying distances from the anterior surface of the neck of the scapula. This last feature was more pronounced in cases with extensive labral detachments Such a defect com

Bone Changes. Varying degrees of erosion and eburnation were found on the anterior lip of the glenoid fossa in cases in which there were labral detachments In one instance, a large irregular defect was demonstrable, leading to the conclusion that a fragment of bone had been sheared away from this area (Fig 228) Some osteophytes were observed on the anterior surface of the neck in three cases with extensive labral detachment

Thirty seven of the 56 cases were studied roentgenographically with the humerus in varying degrees of internal rotation Twenty three (62 per cent) disclosed evidence of a defect in the posterolateral region of the humeral head No lesion was demonstrable in 14 cases (38 per cent)

A comparative analysis of the pathology observed in recurrent dislocation and in initial dislocation discloses very little dissimilarity In the recurrent lesion there is added evidence of a repair, fibrosis and secondary changes in soft and bone tissues It was of great significance to note the paucity of complete cuff tears in recurrent lesions as compared with the frequency of these lesions in primary dislocations, indicating that a fresh dislocation is followed by very active reparative processes

Discussion. Many observers are of the opinion that labral and capsular detachments from the anterior glenoid rim and the capular neck are essential causative factors in recurrent dislocations A smaller group contends that the defect in the humeral head plays the major role in producing this lesion Yet others maintain that both lesions may be responsible for the tendency to recurrences The author is unable to accept these concepts as the true causative factors in recurring dislocation because other observations fail to support such premises

In Chapter 3 it was recorded that some degree of labral detachment was a frequent observation after the third decade, the extent and the severity of this abnormality increasing with each subsequent decade After the sixth decade it was demonstrable in approximately 100 per cent of the specimens.

The severity and the frequency of the lesion was the same, both in a series of cadaver specimens and in a series of post mortem specimens in which a negative shoulder history had been obtained prior to death From this observation alone it is reasonable to assume that detachment of the labrum is associated with advancing age Moreover, its intimate relationship to the glenohumeral ligaments and the biceps tendon render it vulnerable to stresses, chiefly distracting forces, which play a part in its detachment from the glenoid rim

Clinical experience teaches that recurrent dislocations are common in the earlier decades but rare after the fourth. Yet, the afore-mentioned investigation reveals that in the decades in which labral detachment are most frequent and severe recurrent dislocations are rarely encountered In the light of these observations one is forced to conclude that some agent other than labral and capsular lesions as described by Bankart and many others, plays a greater role in the tendency to recurrent dislocation

As previously noted, recurrent dislocation is a self limiting disease Many individuals had in early life numerous recurrences which without treatment, steadily decreased as the individuals approached middle life Finally no more occurred This is readily understandable when one recalls that the musculotendinous cuff exhibits manifestations of a degenerative process characterized by fibrosis of all soft tissue particularly the subsynovial layers and fibrous capsule shortening and loss of elasticity as early as the third decade Such features increase in severity from decade to decade Figure 217 represents graphically the gradual decrease from early to later decades in the range of external rotation. It is obvious that the same process which is responsible for loss of external rotation also cures recurrent lesions and restores stability of the glenohumeral joint

prises the classical Bankartian lesion" Eight cases (15 per cent) disclosed the labrum to be firmly anchored to the glenoid margin by its capsular border however its glenoid border was free like a meniscus

It becomes obvious that it is impossible for the head to pierce the capsule in the anterior portion of the joint unless it is forced through a rent in the anterior portion of the cuff or through a rent in the inferior

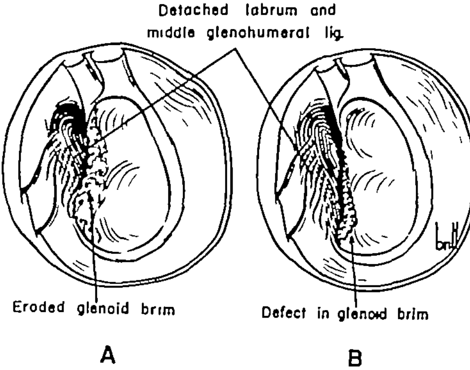


Fig 228 (A) Bony alterations observed along the anterior lip of the glenoid cavity (B) A large defect in the anterior and inferior portion of the glenoid cavity suggests the possibility that a piece of bone was sheared away from this region

Many of the detached labra disclosed advanced fraying shredding and thinning (Fig 226)

At this point it should be recalled that the fibrous capsule in the anterior portion of the glenohumeral joint is not as so many believe continuous with the labrum but is projected mesially as far as the subcoracoid region and then reflected onto the neck of the scapula until it reaches the periphery of the labrum This outpouching of the capsule forms the subscapularis recesses one or two depending upon the anatomy of the variable middle glenohumeral ligament. Such an arrangement was observed in 88 6 per cent of the specimens studied, only 11 4 per cent revealed the capsule continuous with the labrum and in these there were no subscapularis recesses (Fig 227)

capsule below the lower border of the subscapularis muscle The head therefore, in recurrent dislocations lies in the subscapularis recess or recesses which are stretched to accommodate it The middle and the inferior glenohumeral ligaments may be the only feeble barriers to dislocation.

Glenohumeral Ligaments and Subscapularis Recesses. In many instances the middle ligament could not be identified. In a few small shreds of tissue indicated the remains of the ligament. In most shoulders the inferior ligament was discernible, but it was greatly attenuated and stretched All shoulders revealed marked stretching of the subscapularis recesses and one could pass a probe mesially on the anterior surface of the neck of the scapula as far back as the coracoid process

are not infrequent postoperative complications.

By this method, the *intracapsular portion* of the biceps tendon is converted into a suspensory ligament for the head of the humerus. At this point it should be recalled that the biceps tendon is continuous with the posterior and the anterior portions of the labrum glenoidale Also as the result of normal wear and tear and the distracting influence of the biceps tendon on the labrum, there is a gradual separation of *this structure* from the glenoid rim This is manifest as early as the second decade and increases in severity in each subsquent decennium

Therefore it becomes readily understandable that the added pull upon the labrum subsequent to suspension of the humeral head on the biceps tendon enhances labral detachment from the glenoid cavity thereby *defeating the very purpose for which the* operation is performed In the author s opinion labral detachment is the most common cause for failure of the Nicola procedure. This feature was clearly demonstrable in 6 instances of redislocation following a Nicola operation Another technical error that may be responsible for failure is placing the drill hole too close to the periphery of the articular surface of the humeral head. Disintegration or rupture of the new suspensory ligament may be responsible for some failures

Henderson s tenosuspension operation, rather popular at first is now used less frequently A high proportion of failures follows this procedure. Pain (1948) *recorded* that recurrences took place in 9 of 13 cases in which a fascial or tendon sling operation was done Redislocation occurred in every case in which a fascial sling was employed and in 4 of 7 cases in which the peroneus longus tendon was used. On the other hand, Henderson (1943) *reported good results in* 94 per cent of the cases in his series

Bone Block Operation The mechanical objective of these procedures is to produce in front of the humeral head a bony block which prevents the head from being levered out of the glenoid fossa Speed used a tibial graft for this purpose, while Eyre Brook *utilizes an iliac graft* Oudard, in addition to shortening the subscapularis tendon inserted between the tip and the base of the coracoid process a bone graft which extended in front of the glenohumeral joint or turned down in front of the subscapularis half of the coracoid process All these procedures are formidable and technically difficult

Plastic Procedures on the Capsule and the Tendons All plastic procedures aim to build a soft tissue barrier in front of the humeral head, thereby preventing its displacement out of the glenoid cavity Gallie and LeMesuier construct a new ligament of fascia, which later passes through drill holes in the scapula and the head of the humerus They report only 7 redislocations in 175 cases

Bankart conceived his operation on the premise that labral detachment is the "essential lesion ' responsible for redislocation He attempts to restore the normal anatomy of this region by suturing the labrum, or, if the labrum is attenuated he sutures the capsule to the scarified glenoid margin Statistical studies of end result studies from *numerous sources reveal a high percentage* of cures Bankart himself never has had a failure and attributes reported recurrences to technical errors

The operation is difficult and should be performed only by surgeons who are familiar with the topographic anatomy of this *region External rotation* is definitely restricted by this method Adams notes in 18 cases the average range of *external rotation* to be 51° The author is in agreement with many other observers that the success of the procedure depends upon the resulting restriction of external rotation and not on the reattachment of the capsule or labrum to the rim of the glenoid fossa

The Putti Platt *operation which was performed* first by Valtancoli in 1925, is simpler than the Bankart operation and produces equally good results Here again

Pathogenesis of Recurrent Dislocation of the Shoulder

The writer is of the opinion that capsular, labral lesions and humeral head defects are not the prime causative agents of recurrent dislocation They are changes associated with aging but they may be produced or aggravated by trauma Neuromuscular imbalance chiefly of the short rotator muscles, is the most important single causative factor Such a neuromuscular state follows severe stretching of, and direct injury to, the involved muscles (particularly the subscapularis muscle) at the time of injury Pronounced capsular stretching and enlargement of the bursal recesses to accommodate the head are secondary adaptive changes. Repeated dislocations increase the neuromuscular imbalance hence increasing the tendency toward recurrence until nature overcomes the laxity of all tissues by a progressive process of fibrosis, which limits external rotation and stabilizes the glenohumeral joint

If the afore mentioned concept of the pathogenesis of recurrent dislocations is accepted it becomes apparent that such a complication may follow any initial mechanism of anterior dislocation provided that the short rotators particularly the subscapularis muscle are severely stretched and traumatized and that the primary dislocation has not been treated adequately The writer is in total disagreement with Bankart s postulate that recurrent dislocation is a different lesion than ordinary acute traumatic dislocation and that it can occur only in the presence of capsular or labral detachment An essential or Bankartian lesion does not exist.

Capsular and labral lesions as well as defects in the humeral head have been given an undeserved place of importance in the pathology of recurrent dislocation. It has been revealed clearly that they are normal degenerative changes associated with wear and tear and senescence—although it must be admitted that trauma plays a part in their formation.

Treatment

Prevention. Adequate and prolonged immobilization of the arm in internal rotation in young individuals is an essential phase of the treatment of initial dislocations (see Treatment of Acute Anterior Dislocations)

Operative Procedures. Numerous surgical technics have been devised to stabilize the glenohumeral joint Some of these are simple operative procedures others are difficult Excellent results have been claimed for all the different methods of approach yet, critical analysis of the end results discloses an alarmingly high percentage of failures Evaluation of the mechanical principles upon which each procedure is based allows the following conclusions

Suspension Operations The mechanical objective of such procedures is to create a suspensory ligament for the humeral head from fascia or a tendon which will confine the movements of the head within the glenoid cavity thereby preventing subluxation or dislocation

Nicola s operation has been greatly popularized because of its simplicity Reliable end result studies have revealed that this procedure has not come up to the expectations of its supporters Hobart (1938) noted 8 recurrences in a series of 132 Nicola procedures Adams (1948) reported 21 failures in 59 Nicola operations (36 per cent) Many surgeons believe that this procedure is the one of choice in adults not engaged in strenuous occupations.

The writer feels however that this procedure never is indicated because it is mechanically and anatomically unsound. Moreover pain is a frequent distressing sequel to the Nicola operation The pain undoubtedly results from direct injury to the articular cartilage of the humeral head or to the interposition between the articular surfaces of the ligament, which gives rise to an internal derangement of the shoulder not unlike that observed in the knee joint with a torn meniscus. Then too disturbing snapping and clicking sensations within the joint during certain movements of the arm,

its original insertion onto the humeral shaft (Fig 229)

Magnuson Operation (modified) An S-shaped skin incision is made on the anterior aspect of the shoulder, beginning at the inferior margin of the acromioclavicular joint The interval between the deltoid and the pectoralis major is developed, taking care not to injure the cephalic vein, which is retracted medially with the pectoralis major muscle By external rotation of the shaft of the humerus, the subscapularis tendon comes into view as it inserts into the lesser tuberosity A blunt dissector is passed under the subscapularis tendon in order to determine more clearly its upper and lower borders An incision is made in the interval between the supraspinatus and the subscapularis muscles beginning proximal to the blending of the subscapularis tendon with the fibrous capsule and the incision is continued to the anterior lip of the bicipital sulcus

A second incision the same length as the first is made along the lower border of the scapularis muscle. The tendon between the two incisions is then freed from the anterior lip of the bicipital groove by sharp dissection. Retraction medially of the tendon and the capsule affords a clear view of the humeral head the anterior glenoid margin and the anterior portion of the synovial capsule with its glenohumeral ligaments and bursal recesses

The greater tuberosity is visualized by internal rotation of the arm By means of a suture through its substance, the subscapularis is then pulled across the bicipital groove to a point below the greater tuberosity and its site of reattachment is determined The tendon should be anchored to the humeral shaft below the level of its original insertion under moderate but not severe tension With a thin osteotome a slot one-quarter of an inch wide and as long as the width of the subscapularis tendon is made parallel with the posterior lip of the bicipital groove below the greater tuberosity Three or 4 fine drill holes are then made in the posterior lip of the newly formed slot, and the end of the tendon is buried in the bony trough with silk mattress sutures The upper border of the subscapularis muscle is approximated to the supraspinatus muscle by side-to-side sutures, while its lower border is sutured to the capsular tissues under the head of the humerus

Considerable restriction of external rotation is demonstrable at the completion of the procedure The subscapularis muscle and the tendon fibers can also be seen to form a firm sling under the head on abduction of the arm in internal and external rotation The procedure is completed by wound closure in layers with interrupted sutures

Postoperative Treatment For the first two weeks, the arm is fixed to the side in a plaster-of Paris shoulder swathe (Fig 198) For the next 2 weeks the arm is kept in a sling Motion is then begun, but not permitted above the horizontal plane for 2 more weeks Forceful external rotation during this period is prohibited, but full resumption of all motions should be attained by the eighth week. As a rule, abduction is restricted a few degrees, and external rotation may be restricted as much as 50 per cent However, this produces no functional disability and is assurance against redislocation The amount of external rotation lost is a small price to pay for the cure of such a disabling malady by so simple a surgical procedure

Bankart Procedure (Cave and Rowe) Exposure of the anterior region of the glenohumeral joint is obtained by the straight deltopectoral incision or by the S-shaped incision described by Hitchcock and Bechtol Even better visualization of the entire cuff and inside of the glenohumeral joint is obtained by McLaughlin s transacromial incision The author prefers this incision to any other for operative procedures on the cuff or inside the joint (see Chap 11, pp 386-387)

The interval between the deltoid and the

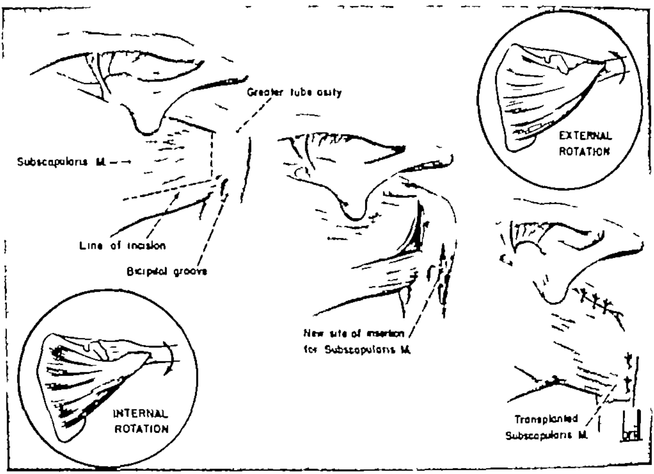


FIG 229 Magnuson operation (modified) for recurrent dislocation The end of the subscapularis tendon is transferred to a bony trough below the greater tuberosity and parallel to the posterior lip of the bicipital groove

the range of external rotation is decreased —which feature is obviously responsible for the satisfactory results

Magnuson conceived a procedure whose simplicity and effectiveness are being recognized by many workers By transferring the subscapularis tendon from the lesser to the greater tuberosity the range of external rotation is diminished hence redislocation does not occur

Discussion. A critical analysis of the many operative procedures devised for redislocation reveals that the essential feature which effects a cure is restriction of external rotation Regardless at what region of the glenohumeral joint or at what components of the joint the operative attacks are aimed limitation of external rotation will effect a cure in the great majority of cases This is also nature s method of eliminating the disability Therefore the simplest procedure which will bring about restriction of the range of external rotation eventually will be adopted uniformly

Magnuson points out that by the transference of the subscapularis tendon to the greater tuberosity a musculotendinous sling or cup is formed around the humeral head in both external and internal rotation which counterbalances the powerful pull of the adductor muscles (pectoralis major latissimus dorsi and teres major) which in turn tend to force the head downward and forward It is the author s opinion that the Magnuson procedure properly performed, will supplant all other operations

The author has slightly modified the operation in order to increase the efficiency of the musculotendinous sling This has been accomplished by transferring the subscapularis tendon across the bicipital groove and anchoring it at a slightly lower level than

prove to be exceedingly difficult, as the tendon and the capsule blend into one mass just proximal to its insertion into the lesser tuberosity The interval can be developed laterally only as far as this fusion area. The subscapularis tendon is divided about one half an inch from its bony insertion and is allowed to retract medially The an

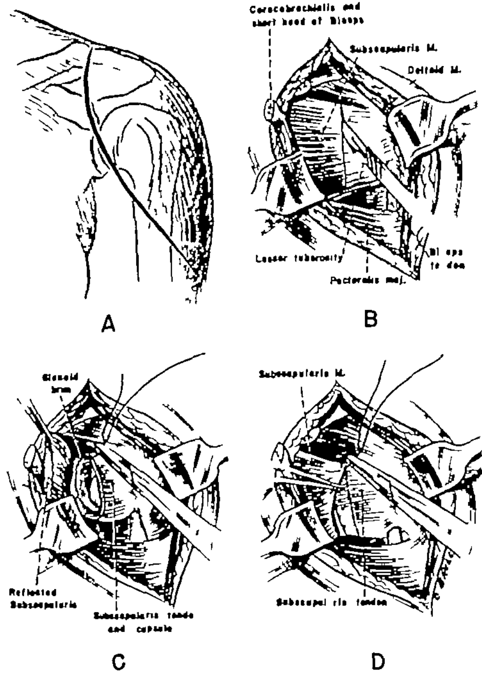


Fig 231 Putti Platt Operation. (A) Anterior deltopectoral inci sion. (B) Conjoined tendon of the coracobrachialis and short head of the biceps tendon has been divided and retracted medially and downward. Subscapularis tendon is divided 1 inch from its insertion the incision is also carried through the fibrous capsule. (C) With the arm rotated internally the lateral flap of the subscapularis muscle is sutured to the soft tissues on the anterior surface of the glenoid rim or to the labrum or occasionally to the under surface of the capsule and the subscapularis muscle. (D) The medial capsular flap is su tured to the outer surface of the lateral subscapularis tendon, thereby overlapping the first suture line. Finally the medial subscapularis flap is tacked to the tendinous portion of the cuff

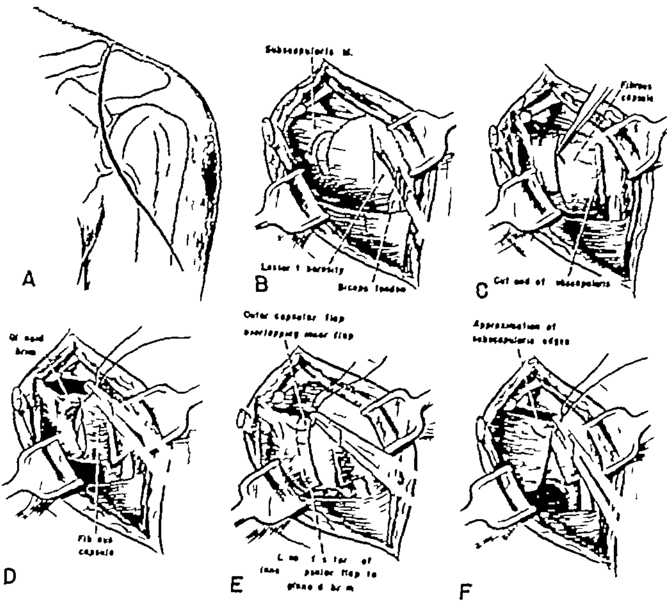


FIG 230 Bankart Operation (A) Deltopectoral incision (an S-shaped skin incision may be substituted) (B) Coracoid process has been sectioned and retracted medially with the coracobrachialis and short head of the biceps tendon The subscapularis tendon is sectioned ½ inch from its bony insertion (C) The subscapularis muscle is peeled off the fibrous capsule and retracted medially the capsule is opened by a 2 inch vertical incision 1 centimeter from the glenoid margin (D) four drill holes are made in the glenoid brim, and the lateral capsular flap is sutured to the bony margin of the glenoid fossa. (E) Medial capsular flap is overlapped and sutured to the lateral flap (F) Divided ends of the subscapularis tendon are approximated by interrupted silk or cotton sutures.

pectoralis major muscles is developed as far as the clavicle from which the deltoid muscle is detached partially and retracted laterally bringing into view the coracoid process and the tendons of the coracobrachialis the short head of the biceps and the pectoralis minor muscles With an osteotome the coracoid process is sectioned and its tip is retracted downward and medially with the muscular attachment

External rotation of the humeral shaft brings into clear view the subscapularis tendon the lower border of which is marked by a plexus of veins. Division and ligation of these vessels provides an almost blood less field

The interval between the subscapularis tendon and the capsule is developed medially as far back as the anterior glenoid margin. This part of the procedure may

FIG 233 The Nicola Operation The biceps tendon is converted into a suspensory ligament for the head of the humerus

tendon, thereby overlapping the first suture line. Further plication is provided by drawing the medial segment of the subscapularis muscle over the second suture line and anchoring it to the tendinous cuff over the greater tuberosity or the bicipital groove Resuture of the conjoined tendon completes the operation At this point in the procedure, external rotation should be limited to midposition of the arm Closure of the wound in layers terminates the operation

POSTOPERATIVE TREATMENT After-care is similar to that recorded following the Bankart and the Magnuson operations

Henderson Procedure. About 2 inches below the superior surface of the acromion process a curved skin incision is made from the anterior to the posterior aspect of the shoulder The superior flap is reflected upward as far as the acromioclavicular joint, exposing the deltoid muscle and the acromion process. A drill hole (10 mm. in diameter) is made transversely through the acromion process. By blunt dissection a small opening is made in the anterior deltoid fibers and another in the posterior fibers exposing the anterior and the posterior surfaces of the greater tuberosity A second transverse drill hole, paralleling the first is made through the greater tuberosity A segment of tendon 10 inches long and half the thickness of the whole tendon is removed from the peroneus longus tendon of the leg on the affected side It is passed through the drill holes and sutured to itself thereby forming an extracapsular suspensory ligament for the head of the humerus (Fig 232)

POSTOPERATIVE TREATMENT The arm is immobilized to the patient s side by a sling or swathe for 10 days Active mobilization is then started, aided by physical therapy

Nicola Procedure The humeral head is exposed through an anterior incision beginning above the coracoid processes and continued distally from 4 to 5 inches The cephalic vein is identified and displaced medially with the pectoralis major muscle By external rotation of the humerus, the intertubercular sulcus and the transverse humeral ligament are visualized By division and retraction of the transverse humeral ligament the biceps tendon is seen within the bicipital groove It is exposed further by dividing the capsule parallel with the fibers of the musculotendinous cuff At *the lower end of the bicipital groove* two silk traction sutures are passed through the tendon which is then divided between the sutures A traction suture on the distal end of the tendon ensures against its retraction down the arm By means of a hand gauge

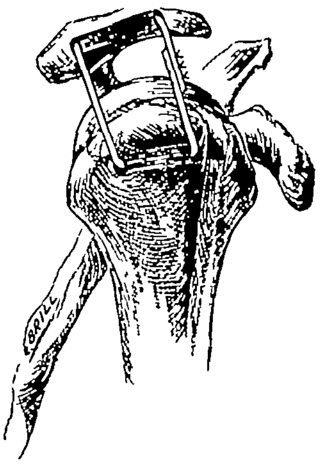


Fig 232 Henderson s tenosuspension operation for recurrent dislocation.

terior margin of the glenoid rim and the capsule (which in this region forms the roof of the subscapularis recesses and is very thin) are identified readily The interior of the joint is exposed by a 2 inch vertical incision approximately 1 cm from the gle noid margin hence creating a lateral and mesial capsular flap

The anterior surface of the glenoid rim is roughened with a fine curette Four drill holes are then made in the rim with a right angle dental drill The lateral capsular flap is approximated and sutured to the bony rim. The mesial flap is lapped over the suture line and tacked to the lateral flap by interrupted sutures. Continuity of the subscapularis tendon is restored by resuturing its divided ends by interrupted silk sutures Finally the tip of the coracoid process is sutured to the base and the wound is closed in layers

Postoperative Treatment This phase of the treatment is identical with that described for the Magnuson operation

Putti Platt Procedure (H. Osmond Clarke) This operation can be performed readily through a transacromial incision or through the anterior approach as described for the Magnuson and Bankart operations Osmond Clarke utilizes an anterior incision extending inward along the outer third of the clavicle and then downward for approximately 6 inches The incision curves along the medial margin of the coracoid process The conjoined tendon (the coracobrachialis and the short head of the biceps brachii) is isolated and divided from the coracoid process, care being taken to leave a proximal stump sufficiently long to facili tate subsequent resuture By gentle retrac tion the conjoined tendon is displaced downward and medially However, care must be taken to avoid injury to the musculocutaneous nerve or the axillary vessels and nerves which run along the medial border of the coracobrachialis muscle.

External rotation of the shaft brings into view the subscapularis muscle and tendon, its lower border being identified by a plexus of veins which are carefully divided and tied The tendon is elevated by a blunt sector passing beneath it from above or below and then is divided one inch from its insertion This incision also divides the fibrous capsule thereby opening the joint cavity and providing visualization of the interior of the glenohumeral joint.

While holding the arm internally rotated the lateral flap of the subscapularis muscle is sutured to the soft tissues on the anterior surface of the glenoid rim or to the labrum. It may be necessary to suture the tendon to the undersurface of the capsule and the subscapularis muscle

In such instances the anterior surface of the neck of the scapula is scarified by a fine osteotome Four interrupted silk sutures suffice to anchor the lateral end of the muscle to its new bed The medial flap of the capsule is then tacked to the outer surface of the lateral portion of the subscapularis

POSTERIOR RECURRENT DISLOCATION

This is a rare lesion, but it may follow a primary traumatic dislocation or occur spontaneously without history of injury Frequently it is bilateral Most observers make a distinction between recurrent and habitual dislocation.

Recurrent dislocation usually follows a violent injury which produces a posterior dislocation It tends to recur at irregular intervals when the arm is subjected unduly to specific stresses.

Habitual dislocation may result from an acute primary injury, but more frequently it occurs spontaneously without history of trauma, and in many instances it is bilateral The lesion occurs every time the arm is elevated in the coronal or frontal plane particularly if it is raised in internal rotation A recurrent lesion may become habitual

PATHOLOGY

The pathologic findings essentially are those recorded for anterior dislocation. Stripping of the capsule and the labrum from the posterior glenoid rim has been observed in some cases In others the labral and the capsular attachments are intact, but the capsule is stretched and pouches out under the external rotators The latter condition is more frequently encountered in the habitual luxations Regardless of the local abnormalities there is loss of normal tonicity of the rotator muscles, particularly the external group This is evidenced by their laxity

Again, it becomes apparent that the local changes are not responsible for recurrences, but rather that the true etiologic factor is a neuromuscular in-co-ordination or imbalance which may be inherent, as in the bilateral habitual luxations (which occasionally are observed in more than one member of the same family) Again it may be the sequel of violent trauma to the local neuromuscular apparatus sustained at the initial dislocation

TREATMENT

The operative procedures which have been described for anterior dislocations have been employed for posterior lesions also In the light of the author s concept of the causative factors, the local alterations are not disturbed Three cases have been cured by simple advancement of the insertion of the infraspinatus and teres minor tendons with the arm in external rotation This procedure restricts internal rotation but increases the efficiency of the external rotators thereby preventing recurrences

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TABLE 1
ANALYSIS OF 23 MAGNUSON PROCEDURES (MODIFIED)

Name	Sex	Age	Date of Operation	Number of Recurrences	Pain	Satisfied
C F	M	28	5 26-48	1	Yes	No
R M	M	23	11 22-47	0	No	Yes
R C	M	30	5 30-48	0	No	Yes
G H	M	24	10- 3-47	0	Occasionally	Yes
W M	M	24	6 28-48	0	No	Yes
A A	M	23	2 30-48	0	No	Yes
M K	M	21	3 21-48	0	No	Yes
F H	M	22	4-29-48	0	No	Yes
J C	M	29	6-25-48	0	No	Yes
J F	M	26	7 30-48	0	No	Yes
W A	M	20	7 19-48	0	Yes	Yes
A A	M	25	8-24-48	6	After Dislocation	No
W S	M	21	3 3-48	0	No	Yes
J N	M	18	11 15-47	0	No	Yes
T J	M	36	8- 4-48	0	No	Yes
D L	M	17	5 21-45	0	No	Yes
W B	M	30	1 21-48	0	No	Yes
C M	F	29	3 26-48	0	Slight	Yes
J C	M	19	8-24-47	0	No	Yes
L B	M	33	6 12-47	0	No	Yes
T N	M	22	8-18-46	0	No	Yes
D O	M	29	10-15-47	0	No	Yes
J N	M	22	2 23-48	0	No	Yes

Analysis of Cases

Total number of cases	23
Age range	17 to 33 years
Males	22
Females	1
Recurrences of dislocation	2 (8.7 per cent)
Pain present	2
Not satisfied with operation	2
Satisfied with operation	21
Period of observation	17 mo. to 3½ yr

a quarter inch tunnel is made beginning at the lower end of the bicipital groove and emerging out of the center of the articulating surface of the head of the humerus Nicola stresses that the exit of the tunnel be in the center of the head of the humerus

The proximal segment of the biceps tendon is stripped of its synovial sheath and then by the use of a wire loop its traction suture is passed through the tunnel from above downward Steady traction on the silk suture pulls the tendon through Continuity is restored by suturing the proximal and the distal ends of the tendon which in turn is anchored through drill holes to the *transverse humeral ligament* onto the sides of the groove Closure of the capsule is effected by side-to-side sutures of silk The operation is completed by closure of the wound in layers

POSTOPERATIVE TREATMENT The arm is immobilized to the side for 4 weeks by means of a Velpeau dressing Progressive, active stooping exercises are then begun. Physical therapy is a valuable adjunct in that properly utilized it impresses the patient with the importance of active progressive movements necessary for complete restoration of function

POSTERIOR RECURRENT DISLOCATION

This is a rare lesion, but it may follow a primary traumatic dislocation or occur spontaneously without history of injury Frequently it is bilateral Most observers make a distinction between recurrent and habitual dislocation.

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Treatment

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8

Fractures and Fracture-Dislocations of the Upper End of the Humerus

GENERAL CONSIDERATIONS

Optimum management of fractures of the upper humerus is governed by the knowledge of certain anatomic and clinical features peculiar to this region. Prime consideration must be given to the patient as a whole. The local pathology is of secondary importance. The individual's age, sex, occupation and economic plane must be adequately evaluated since these factors have a direct bearing upon the preferred method of treatment.

The ideal objectives in the treatment of the above lesions are (1) normal anatomic restoration of all the involved tissues (osseous and soft tissues) and (2) complete functional return of the extremity and the individual in the shortest period of time possible. Clinical experience, however, makes it clear that both objectives cannot always be achieved and that the first is not essential to achieve the second. One must also appreciate that this principle is applicable only within certain limits and if the limits are exceeded, poor function and pronounced disability are inevitable.

Features peculiar to the shoulder region are:

1. Stability of the glenohumeral joint is not dependent upon the configuration of its bony components, but upon the muscles which motorize it, primarily those comprising the musculotendinous cuff. Incongruity of the glenohumeral surfaces, within reasonable limits, is compatible with good function because the muscular apparatus can adjust itself to changes in the architecture of the bony elements. In the light of such facts, one is justified in accepting deformities of the upper end of the humerus following injury provided that the malalignment can be compensated for by the soft tissue structures. This is particularly true of all impacted fractures of the upper end of the humerus.

2. Motion in the glenohumeral joint is the result of a group of muscles working as a unit, but failure of one muscle of the group to function, regardless of the cause, does not materially affect the over-all performance of the unit. This again is true only within certain limits. For example, perfect shoulder function is attained in cases with complete tears in the musculotendinous cuff provided that the defects are not extensive. If there is severe disruption of the motor apparatus, marked loss of function is the rule unless the lesion is recognized and adequate repair effected.

3. Bony union is assured and not influenced by any method of treatment. Impacted fractures always heal readily. Unim-

pacted fractures heal, provided that the fragments maintain some contact Non union occurs only in fractures with marked displacement of the fragments, as occur in fracture dislocations in which the head lies in the soft tissues at considerable distance from the distal fragment and separated from *it by soft tissue.*

4 The intimate relation of the insertion of the rotator muscles into the tuberosities tends to preserve continuity of fragments in fractures involving this region Continuity is also enhanced by the subacromial bursa which is closely adherent to the superior surfaces of the tuberosities, the periosteum which may be intact at the lower borders of the fragments and to some degree by the biceps tendon which tends to maintain normal anatomic relationship of the fragments.

There are exceptions to these observations Fractures through the anatomic neck may result in complete displacement of the humeral head, the degree of displacement depending upon the violence of the injury (the head may be forced out of the capsule) *Fractures of the tuberosities with retraction* of the fragments denote extensive tearing of the musculotendinous cuffs

In the light of these observations, it becomes obvious that in impacted fractures maintenance of the position of the fragments can be expected without the use of cumbersome apparatus splints or casts which are superfluous and may be harmful

5 Preservation of the gliding mechanism between the different soft tissue strata of the shoulder is essential for rapid and complete restoration of function. Traumatized soft tissue in this region tends to heal rapidly Secondary fibrosis, contraction and loss of elasticity are common sequelae of this reparative process. Early mobilization within safe limits (within the tolerance of pain) is the most effective therapeutic agent available to prevent stiffness and to preserve free movement Early mobilization should be the most important feature of the therapeutic *regimen in patients* over 40 years of age and in the aged in whom there are already varying degrees of degenerative changes in the supportive soft tissue structure resulting from wear and tear and senescence, because such tissues are more likely *to develop protracted stiffness* than the tissues of patients under 30

MECHANISM OF FRACTURES OF THE UPPER END OF THE HUMERUS

Direct violence to the shoulder rarely produces fractures of the upper end of the humerus The overhanging acromion protects the humeral head from the impact of direct forces Trauma of this nature, if of sufficient severity, usually results in either a fracture of the clavicle or disruption of the acromioclavicular joint. In rare instances direct trauma to the point of the shoulder with the arm in dorsiflexion may produce a fracture of the upper end of the humerus

Fractures of this region are produced invariably by the same mechanism that is responsible for dislocation of the humeral head *They result from such indirect violence* as falls on the outstretched arm, during which the arm fails to rotate quickly enough in the right plane to reach the safety of the pivotal position, or it is forced beyond the limits of this enclosure. The tough acromion process acts as a fulcrum at the base of the greater tuberosity, while the shaft of the humerus becomes the long arm of the lever As the arm is forced into hyperabduction the superior rim of the glenoid fossa is wedged between the greater tuberosity and the articular head If the *force continues, either a dislocation or* a fracture of the humerus or a combination of both results Codman recognized a false and a true dislocation.

In a false dislocation the head is levered out of the glenoid cavity without rupture of the inferior capsule which becomes unduly stretched to accommodate the heads Spontaneous reduction occurs as the arm descends to the side from the abducted posi

tion In true dislocation the head is forced through a rent in the capsule and remains in a subglenoid position after the arm is brought to the side Both forms may be accompanied by fractures of the upper end of the humerus

In general the above mechanism is responsible for different lesions in the various age groups In children the weakest point in the upper end of the humerus is its epiphyseal line therefore epiphyseal separation is the most common lesion encountered In youth and manhood after the epiphyseal lines have been obliterated, the osseous and tendinous elements are the strongest tissues in this region On the other hand the capsule is relatively weak and dislocations are more likely to occur If a fracture does occur it is as a rule through the base of the greater tuberosity or the surgical neck Finally in the old age periods the cancellous bone is more or less brittle and weak hence comminution of the upper end of the humerus is a frequent occurrence

Other factors which influence the type of lesion produced by the described mechanism are

1 The severity of the force and the exact point on the humerus at which it is expended The acromion will act as a fulcrum at different points on the tuberosity, depending upon the degree of rotation of the humeral shaft Appreciation of this observation makes it apparent that numerous combinations of fracture lines through this region are possible

2 The weight and the velocity of the falling body

3 The direction the arm takes upon striking the ground before the full impact of the disruptive force is expended If it moves toward the body, an adduction fracture results If it moves away from the body an abduction fracture is produced (Fig 234) In adults the abduction type is more common while in children the adduction form is more frequently encountered the abduction fracture being exceedingly rare (Fig 235)

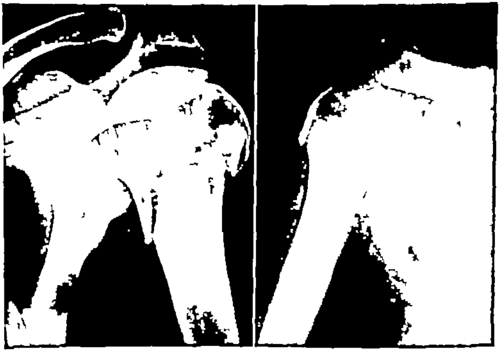

Fig 234 (*Left*) Abduction fracture of the neck of the humerus, resulting from a fall on the outstretched arm the arm moving away from the body

Fig 235 (*Right*) Adduction fracture of the neck of the humerus, resulting from a fall on the outstretched arm the arm moving toward the body

Comminuted fractures of the upper end of the humerus, as previously recorded usually occur in elderly individuals but may occur in any age group After closure of the epiphyses a thin plate of hard bone replaces the epiphyseal lines These partitioning bony plates are readily discernible in humeral heads of the aged They consist of firmer, tougher, more compact bone than the adjacent cancellous bone Codman pointed out that the lines of cleavage of most fractures in this region follow near these old lines of

FIG 236 A disruptive force produced by impingement of the humerus against the acromion (insert) may produce fractures following the planes of the lines of epiphyseal union resulting in 4 main fragments or any combination of these fragments.

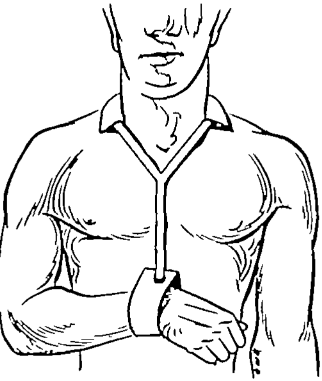

Fig 237 Collar and-cuff sling

epiphyseal union and the head of the bone tends to become divided into four main fragments or various combinations of these four fragments (Fig 236)

Classification of Fractures of the Upper End of the Humerus

Analysis of the various types of fractures which may be possible by the afore-mentioned mechanism permits the following classification from an anatomic viewpoint

1 Fracture of the greater tuberosity
2 Fracture of the lesser tuberosity
3 Fracture of the anatomic neck
4 Fracture of the surgical neck
5 Separation of the epiphysis of the humerus
6 Fracture of the head of the humerus
7 Any combination of the above fractures.
8 Comminuted fractures of the entire upper end of the humerus
9 Fracture-dislocations Any of the above fractures may occur with dislocation of the humeral head

Although such a classification denotes to some degree the topographic anatomy of the fracture, it is of no value from a therapeutic viewpoint The author is in complete agreement with McLaughlin in that fractures of the upper end of the humerus should be divided into two principal groups

1 Fractures requiring no reduction
2 Fractures requiring reduction.

FRACTURES REQUIRING NO REDUCTION

General Considerations

The great majority of fractures involving the upper end of the humerus needs no reduction This is particularly true of all impacted fractures and includes fractures of the surgical neck the anatomic neck, tuberosities, or any combination of the above. Only unimpacted fractures which demonstrate gross disalignment and angulation and surgical and anatomic neck fractures with complete displacement demand repositioning of the fragments As previously stated certain functional and anatomic features peculiar to this region justify this method of treatment They are

1 Anatomic repositioning of fragments

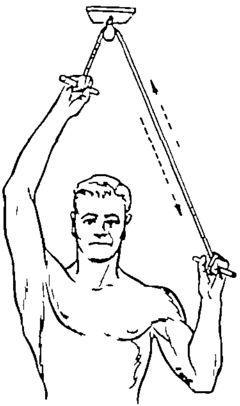

Fig 238 Exercises for shoulder

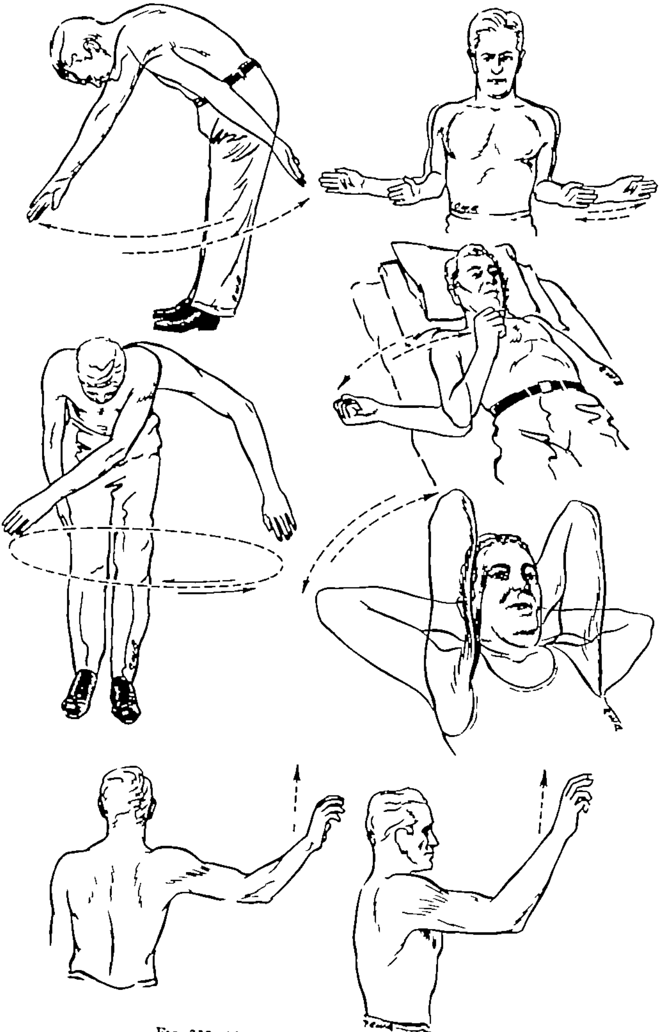

Fig 238 (*Continued*) Exercises for shoulder

is not essential for normal function Clinical experience points out that incongruity of the articular surfaces of the glenohumeral joint is compatible with good function

2 Further displacement of the fragments following the initial violence does not occur, because the musculotendinous cuff, the subacromial bursa and the biceps tend to keep the fragments together

3 Bone healing always occurs except in instances of wide separation of the fragments with interposition of soft tissues

4 Changes in the mechanics of the muscular apparatus within reasonable limits do not preclude good function This is particularly true of the insertion of the short rotators into the head of the humerus

5 Early mobilization of the glenohumeral joint within the limits of pain does not displace the fragments (cf *supra* 2) favors early restoration of function and prevents stiffness by preserving the gilding mechanism between the various soft tissue strata of the shoulder

Management of Impacted Fractures of the Upper End of the Humerus

All cumbersome fixation apparatus such as abduction plaster casts hanging casts splints and braces are definitely contraindicated in the management of this group of fractures. A simple sling and swathe holding the arm to the side suffices It allows early motion and the weight of the arm provides adequate traction at the fracture site Even better is a collar-cuff sling suspending the arm from the neck (Fig 237)

Motion in impacted fractures is started immediately by encouraging the patient to perform stooping exercises (Fig 238) All movements must be within the patient s tolerance of pain—never beyond

If the regimen is carried out properly exercises are done a pecific number of times (from 8 to 10 times) every hour or for a specified period of time (from 3 to 5 minutes) every hour The range of motion and the period of the exercises increases progressively as the intensity of the pain subsides After 3 weeks, the sling may be discarded during the day The swathe is worn only at night to protect the extremity from involuntary movements Two or three days after the injury, wall-crawling and later, pulley exercises are added Free use of the arm within the limits of pain is encouraged at all times, while physical therapy in the form of radiant heat and gentle massage is a valuable adjunct to the treatment. Maximum restoration of function should be achieved in from 8 to 12 weeks

Motion in unimpacted fractures should be performed with greater caution than is sometimes exercised Movements against gravity should not be attempted until there is clinical evidence of sufficient healing to preclude further displacement of the fragments This is manifest by all fragments moving in unison upon gentle internal and external rotation of the humeral shaft. Bony healing sufficient to permit antigravity exercises usually is attained in 2 or 3 weeks.

The above regimen must be adhered to religiously in patients past 40 years of age. Only by such a program the principal feature of which is early mobilization can protracted stiffness and great disability be averted

In general the prognosis in fractures of this group treated by the afore-mentioned method is good. However there are two fractures in this category whose prognosis, regardless of the treatment is invariably poor These fractures are (1) depressed fractures of the greater tuberosity and (2) impacted fractures of the anatomic head into greater tuberosity

Depressed Fracture of the Greater Tuberosity

As a rule it is produced by a direct force on the point of the shoulder when the arm is in dorsal flexion, or by impingement of the greater tuberosity against the acromion process but it may be the result of a telescoping force driving the greater tuberosity against the glenoid during falls with the arm in forward elevation or abduction

Invariably, this injury is complicated by pronounced periosteal injury, extensive injury to the insertion of the musculotendinous cuff, and distortion of the normal configuration of the bicipital groove Because

Fig. 239 Impacted depressed fractures of the greater tuberosity Stiff and painful shoulders are frequent undesirable sequelae of this type of fracture The painful syndrome usually results from a bicipital tenosynovitis, which may be primary or secondary in origin Such fractures often implicate the intertubercular sulcus distorting its configuration.

of extensive periosteal damage, the fracture may be complicated by massive callus formation which impinges against the coraco-acromial ligament or the acromion on elevation of the arm

Distortion of the bicipital groove may interfere with the normal tendon tendon sheath gliding mechanism of the biceps tendon resulting in a bicipital tenosynovitis (Fig 239, *right*) In elderly patients, this lesion may be responsible for the development of frozen shoulder This crippling protracted complication is initiated by a bicipital tenosynovitis which results from trauma sustained at the time of the initial violence or develops gradually following secondary osseous changes in the bicipital groove. Roughening spur formation on the sides and the floor of the groove, and gross obliteration of portions of the sulcus are common sequelae to this form of fracture

Treatment of depressed fractures of the greater tuberosity is similar to that described for impacted fractures Disabling sequelae should be anticipated and treated as soon as they manifest themselves. The prognosis always should be a guarded one

Impacted Fractures of the Anatomic Head into Greater Tuberosity

This lesion is encountered more frequently since the advent of shock therapy The author has seen three instances following convulsive seizures produced by this form of treatment. The anatomic head is driven into the cancellous bone of the tuberosity cutting deeply into the musculotendinous cuff at its line of insertion into the sulcus The intertubercular groove is obliterated, thereby crushing the biceps tendon and obliterating its gliding mechanism

is not essential for normal function Clinical experience points out that incongruity of the articular surfaces of the glenohumeral joint is compatible with good function

2 Further displacement of the fragments following the initial violence does not occur, because the musculotendinous cuff, the subacromial bursa and the biceps tend to keep the fragments together

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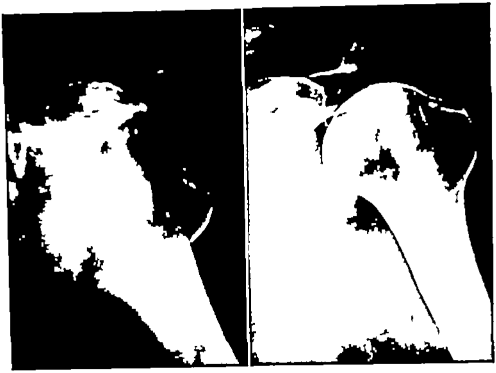

Fig 242 (*Left*) Fracture of the greater tuberosity associated with anterior dislocation of the head of the humerus Note that the acromion has retained its normal position relative to the scapula. (*Right*) Fracture-dislocation depicted at left has been reduced Observe that the greater tuberosity now lies in its normal anatomic position.

mechanical block to abduction and elevation of the arm Its size bearing no relation to the extent of cuff disruption In most instances the fracture line involves the floor of the bicipital groove and some changes in the groove subsequent to healing may be anticipated Such abnormalities comprise spurring irregularity of the floor and the walls of the groove or even obliteration of portions of the groove.

In the light of the afore mentioned pathology it becomes apparent that anatomic repositioning of the fragments and repair of the torn musculotendinous cuff is essential This is achieved by exposing the region by a transacromial incision The fragment is pulled down to its normal site and fixed to the humeral head either by a screw or a wire loop Repair of the cuff is accomplished by the methods described in Chapter 4

Fractures of the tuberosity with retraction are strong indications for surgical intervention Complete anatomic restoration of the bony and soft tissue elements can be achieved only by open operation Treatment by closed methods with the arm in abduction and external rotation results frequently

Fig 243 Fracture of the greater tuberosity and neck of the humerus. The tuberosity fragment has been displaced upward toward the acromion process by the attached rotator tendons.

FIG 240 Impacted fracture of the anatomic head often responsible for stiff and painful shoulders As in depressed fractures of the greater tuberosity this lesion may damage the biceps tendon primarily or (because of changes in the bicipital groove) may interfere with the normal tendon tendon sheath gliding mechanism of the biceps tendon. This patient developed a frozen shoulder

FIG. 241 Comminuted fracture of the greater tuberosity, with minimal displacement

In young individuals uncomplicated bicipital tenosynovitis is the most common sequela while in those past middle life the bicipital affection initiates processes which terminate in frozen shoulder

Treatment of this fracture is similar to that for all impacted fractures As in depressed fractures of the greater tuberosity the prognosis is poor and undesirable sequelae should be anticipated

FRACTURES REQUIRING REDUCTION

FRACTURES OF GREATER TUBEROSITY WITH DISPLACEMENT

As a rule, fractures of the greater tuberosity not complicated by dislocation of the humeral head disclose little or no separation (Fig 241) The same is true of most greater tuberosity fractures associated with dislocation of the glenohumeral joint. The fragments return to their anatomic position after reduction of the dislocation (Fig 242) Occasionally after reduction of a dislocation or when no dislocation has occurred the fragments are widely separated from their normal position They may assume one of two positions (1) the greater tuberosity may be retracted under the acromion (Fig 243) or (2) it may be displaced downward and outward

Fracture with retraction of the tuberosity is equivalent to rupture of the external rotator components of the musculotendinous cuff There may be massive avulsion of the cuff associated with the lesion It is impossible to determine the extent of the soft tissue damage without visualization of the subacromial area The tuberosity retracts under the acromion and acts as a

FIG 246 (*Left*) Abduction fracture of the surgical neck of the humerus. This amount of displacement does not justify manipulation to attain better alignment. (*Right*) Adduction fracture of the surgical neck of the humerus. This amount of displacement is compatible with good function.

pain and muscle spasm preclude adequate examination of the shoulder joint to confirm the diagnosis. Infiltration of the affected area with procaine allows more thorough examination, but abduction of the arm at this time may cause greater separation of the fragments and increase the soft tissue damage Hence it is contraindicated for diagnostic purposes

Optimum management is achieved by the open method, utilizing the transacromial route to expose the subacromial region The fragment is replaced and held in position by wire or screws, and the cuff is repaired by methods previously described. Postoperative treatment then proceeds as in a fracture without displacement

Fracture of the Lesser Tuberosity with Retraction

This lesion is exceedingly rare as an isolated lesion being more frequently encountered in comminuted fractures of the upper end of the humerus and in dislocations of the humeral head The subscapularis muscle pulls the fragment inward to occupy

FIG 247 Nonimpacted abduction fracture with marked angular deformity In this case repositioning of fragments is necessary

Fig 244 (*Left*) Fracture of neck of the humerus without displacement Severe comminution of the tuberosities exists. (*Right*) Impacted fracture of the anatomic neck of the humerus with avulsion and slight upward and outward displacement of a portion of the greater tuberosity

Fig 245 Impacted fracture of the neck of the humerus with extensive comminution of the head

in dismal failure, leaving the patient with protracted or permanent disability

Following open reduction of the fracture and repair of the cuff with the arm at the side the injury is treated in every respect similarly to impacted fractures of the upper end of the humerus Occasionally the fragment may exhibit extensive comminution so that repositioning and maintenance of reduction as described is not feasible. Excision of the fragments is the procedure of choice in these instances The rotator cuff is then reattached to the humeral head wherever it will reach with the arm at the side, by methods previously described in Chapter 4 This same approach to the problem may be necessary in old cases in which it is impossible to pull the fragment to its anatomic position If a dislocation has been present motion at the shoulder joint is kept below the horizontal for 4 weeks.

In fractures of the greater tuberosity with downward and outward displacement, one must assume that there is also a concomitant rupture of the cuff As in all acute traumatic lesions about the shoulder joint,

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This lesion is exceedingly rare as an isolated lesion being more frequently encountered in comminuted fractures of the upper end of the humerus and in dislocations of the humeral head The subscapularis muscle pulls the fragment inward to occupy

FIG 247 Nonimpacted abduction fracture with marked angular deformity In this case repositioning of fragments is necessary

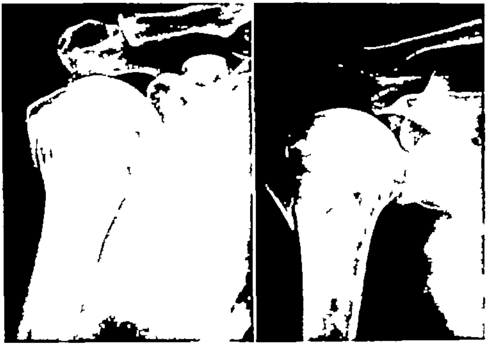

Fig 244 (*Left*) Fracture of neck of the humerus without displacement Severe comminution of the tuberosities exists. (*Right*) Impacted fracture of the anatomic neck of the humerus with avulsion and slight upward and outward displacement of a portion of the greater tuberosity

Fig 245 Impacted fracture of the neck of the humerus with extensive comminution of the head.

in dismal failure leaving the patient with protracted or permanent disability

Following open reduction of the fracture and repair of the cuff with the arm at the side the injury is treated in every respect similarly to impacted fractures of the upper end of the humerus. Occasionally, the fragment may exhibit extensive comminution so that repositioning and maintenance of reduction as described is not feasible. Excision of the fragments is the procedure of choice in these instances The rotator cuff is then reattached to the humeral head wherever it will reach with the arm at the side, by methods previously described in Chapter 4 This same approach to the problem may be necessary in old cases in which it is impossible to pull the fragment to its anatomic position If a dislocation has been present motion at the shoulder joint is kept below the horizontal for 4 weeks.

In fractures of the greater tuberosity with downward and outward displacement, one must assume that there is also a concomitant rupture of the cuff As in all acute traumatic lesions about the shoulder joint,

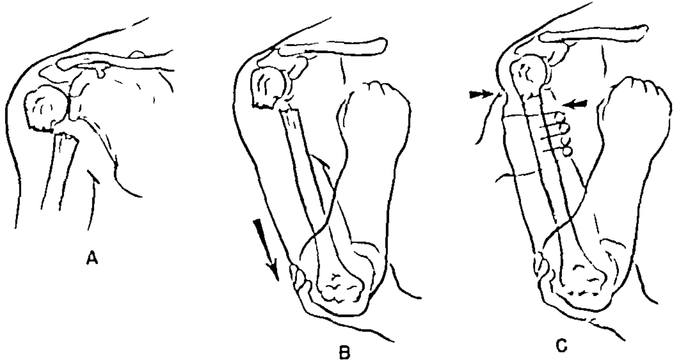

Fig 248 Method of reducing completely displaced fractures of the surgical neck by traction on the slightly flexed and adducted arm

have fallen into proper alignment, traction is released gradually allowing them to engage The arm is then carefully brought to the patient s side and immobilized by a collar and-cuff sling and swathe (Fig 248)

Postreduction management is similar to that of unimpacted fractures requiring no reduction Movement in the fingers, the wrist and the elbow are started immediately After 2 weeks, sufficient bony healing has taken place to permit antigravity, pendulum exercises As a rule after 3 weeks all fragments move in unison upon rotating the humeral shaft indicating that movements against gravity may be begun with no fear of displacement

The great majority of displaced surgical neck fractures can be reduced by the above manipulative method In most instances, the position of the fragments will not be lost when traction is released and when the arm is brought to the side In a goodly number, however because of the characteristics of the fragments reduction cannot be maintained without traction

In such instances the patient is placed in a recumbent position the fracture is reduced as described above and necessary traction is provided by suspending the flexed and adducted arm from an overhead frame Skeletal traction (*wire or pin through the olecranon*) is the simplest and most efficacious form of traction (Fig 249) It also permits early mobilization of the joints of the fingers and of the wrist Within 2 weeks healing will have progressed sufficiently to allow all fragments to move in unison upon internal and external rotation of the humeral shaft This denotes that traction may be removed with safety and the arm may be brought to the side Subsequent treatment proceeds as in the case of fractures of this region which require no reduction

In some instances all manipulative measures fail to achieve a satisfactory reduction of the fracture Traction with the arm in flexion and adduction as described above will not bring about repositioning of the fragment It becomes necessary in these difficult fractures to resort either to open procedures or to apply traction with the arm in slight abduction Occasionally, this last method will produce a satisfactory reduction when all other closed methods fail

The arm is placed in from 45° to 60° ab-

a position between the humeral head and the coracoid process It now acts as a bony block to internal rotation flexion and elevation of the arm Restoration of the fragment to its normal position is essential and can be accomplished only by open operation An anterior deltoid splitting incision provides adequate exposure for this procedure As a rule, the fragment is readily tacked in place by interrupted sutures passing through drill holes which have been made in the detached fragment and in the edges of the defect in the humerus

Postoperative management is the same as in fractures without displacement Care must be taken to refrain from early forceful external rotation exercises which are likely to pull the lesser tuberosity from its anchorage

Fractures of the Humeral Neck

Fractures of the humeral neck are common lesions and may occur in all age periods they are encountered more frequently in adults only rarely in children The lesions may be subperiosteal and incomplete without separation of the fragments as is usually observed in children On the other hand depending upon the direction the arm takes as the patient falls on the outstretched hand (see Mechanism of Fractures of the Upper End of the Humerus) the humeral shaft may be displaced into an abducted or adducted position in relation to the proximal fragment (humeral head) as shown in Figure 246 Not infrequently the fracture may be a concomitant lesion of extensive comminution of the upper end of the humerus (Fig 245)

As previously recorded no impacted fracture regardless of the type or the degree of deformity, requires reduction Repositioning of the fragments is warranted only in unimpacted fractures with complete displacement and in those with severe angular disalignment which, if not eliminated or decreased, would provide a mechanical impediment to normal glenohumeral motion (Figs 246 and 247)

Surgical Neck Fractures with Complete Displacement

This is not a common lesion The proximal fragment may be abducted slightly and rotated externally by the short rotator muscles inserting into the greater tuberosity As a rule the head fragment (except for slight abduction) is not materially affected by muscle pull, because the pull of the short external rotators is almost completely counterbalanced by that of the subscapularis muscle

The distal fragment, completely separated from the head fragment, is displaced upward forward and inward Upward displacement is the result of the direction of the initial violence and the pull of long muscles paralleling the shaft of the humerus (deltoid triceps biceps and coracobrachialis) Forward displacement is affected by the pectoralis major, the teres major and the latissimus dorsi Inward displacement by the pectoralis major the short head of the biceps and the coracobrachialis

Treatment—Manipulative Reduction with Arm in Adduction and Flexion. Complete muscle relaxation is essential to attain reduction with minimum force and is best attained by general anesthesia Pentothal Sodium is an excellent agent for this purpose With the patient in the recumbent position an assistant makes steady traction on the arm first in line with the long axis of the body Then traction being maintained, the arm is adducted across the anterior surface of the thorax and flexed in relation to the frontal plane of the body By this maneuver the length of the arm is restored and all forces responsible for the deformity are eliminated Flexion and adduction relax the pectoralis major the teres major and the latissimus dorsi while steady traction overcomes the deforming forces of the long muscles paralleling the humerus.

After arm length has been restored, the operator places his hand in the axilla and pushes the upper end of the shaft fragment outward while firm inward pressure is made on the head fragment. When the fragments

rovascular structures in the axilla are apt to be severely stretched and traumatized Moreover, abduction maneuvers tend to separate the fragments and to increase the forces responsible for displacement of the distal fragment Also the pectoralis major the teres major and the latissimus dorsi are stretched unduly Only in exceptional cases which fail to respond to adduction methods is mild abduction of the extremity (from 45° to 60°) permissible to effect a reduction However the reduction always must be ac companied by continuous traction

Abduction apparatus, designed with or without traction in order to make the patient ambulatory never should be used They are cumbersome and difficult to apply moreover they fail to maintain proper re duction In fact they increase the deformity and are responsible for marked functional disability The author has seen one patient who was treated by the abduction or air plane splint, healing took place with pronounced abduction deformity of the distal fragment When the arm is lowered, the upper end of the fragment abuts against the inferior glenoid rim so that the arm cannot be brought to the side but projects from the trunk at an angle of 45

Fractures of the Anatomic Neck of the Humerus

Fractures through the anatomic neck, as single lesions are rare and usually occur in combination with other fractures of the upper end of the humerus and with fracture dislocation of the humeral head In many instances the capital fragment includes one or both tuberosities It usually occurs in adults past middle life, rarely in children Depending upon the direction which the ex tremity takes as the patient falls on the out stretched hand, the capital fragment is forced into an abducted or adducted posi tion, the abduction type being slightly more common Generally, the fragments are im pacted since the fracturing force drives the upper end of the humeral shaft into the cancellous bone of the capital fragment

The intracapsular fragment in spite of the noted impaction may be severed from all its blood supply Fortunately, in many instances it maintains continuity with some of the other fragments, particularly the lesser tubercle which may have adequate circulation Hence, some nourishment to the intracapsular fragment is assured Dimin ished or complete obliteration of the blood supply to this fragment may be followed by avascular necrosis, which may not manifest itself for from 18 to 24 months after the injury This complication results in a stiff and painful shoulder joint In the light of the above information one must not con sider these fractures lightly The prognosis should be guarded, and the disabling com plication of avascular necrosis of the anatomic head should be anticipated in a certain percentage of these cases

Treatment. Regardless of the type of fracture or the extent of the deformity, no reduction is indicated if the fragments are impacted Such cases are treated similarly to other impacted fractures of the upper end of the humerus Repositioning of the frag ments is justified in unimpacted fractures with gross angular deformities or with com plete displacement

Abduction fracture of the anatomic neck with no impaction and complete displacement or gross angulation are reduced by traction on the adducted and flexed arm and manipulation as described for fractures of the surgical neck *Postreduction treatment* is the same as for fractures in this region requiring no reduction If reduction cannot be maintained without continuous traction skeletal traction is employed, as described in surgical neck fractures.

At no time must one be tempted to treat these lesions on an abduction frame or splint These apparatus increase the de formity and allow the fragments to heal with gross *malalignment* Occasionally when closed methods fail to produce the desired reduction, operative intervention is justifiable

Adduction fractures with gross angular

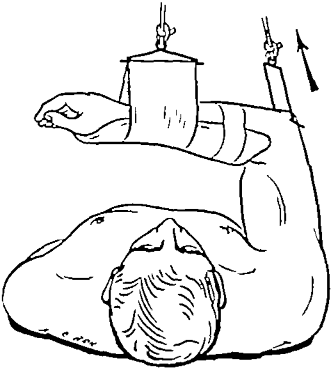

Fig 249 Method of continuous traction to maintain position of fragments following reduction by manipulation as depicted in Figure 248

duction (60° must not be exceeded), and the forearm is flexed at the elbow to 90° Traction is made along the shaft of the humerus by means of a pin or a wire through the olecranon Sufficient traction is applied at the fracture site to restore alignment. Distraction must be avoided (Fig 250) In this position the extremity is in balance as regards the various forces producing the deformity From 45° to 60° of abduction does not put the pectoralis major under undue tension whereas traction restores length and overcomes the forces of the long muscles of the arm After 2 or 3 weeks, healing advances sufficiently to assure maintenance of reduction without traction All apparatus is then removed the patient becomes ambulatory and the fracture is treated in the same way as fractures requiring no reduction

Discussion of Abduction Treatment Manipulative measures with the arm in wide abduction in surgical neck fractures are dangerous procedures, because the neu

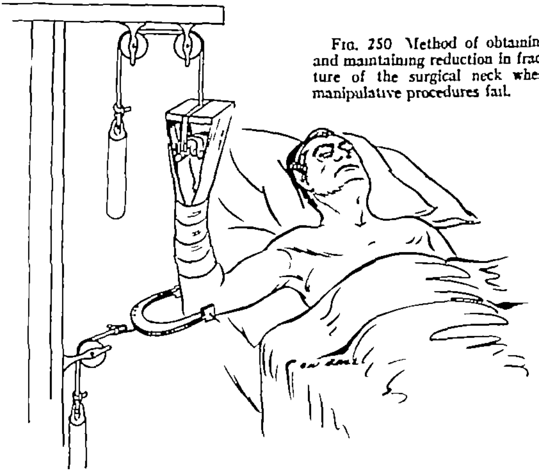

Fig. 250 Method of obtaining and maintaining reduction in fracture of the surgical neck when manipulative procedures fail.

The shaft may be adducted and impacted into the inner portion of the epiphysis, or the epiphyseal fragment may include a small triangular portion of the metaphysis or even a large segment of the upper end of the diaphysis (Fig 251)

Disturbances of growth may occur following trauma to the epiphyseal plate The extent of epiphyseal damage and subsequent growth disturbance cannot be assayed properly by the degree of separation discernible on radiographic examination Gross displacement may be followed by little or no disturbances of bone growth, while marked growth disturbance and gross deformity may occur subsequent to minor displacements. It is evident that treatment of these lesions demands great gentleness Further damage to the epiphyseal plate must be avoided

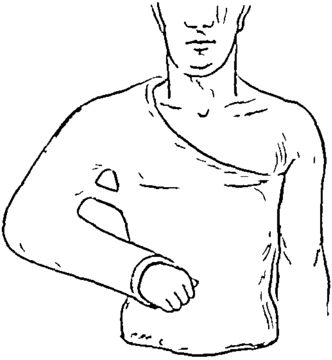

Fig 252 Plaster-of Paris shoulder spica used to immobilize the extremity following reduction of epiphyseal fracture.

Treatment

Management of these lesions should be *guided by the knowledge that nature tends* to adjust and minimize all bone deformities by subsequent bone growth and that all manipulative measures regardless of how *gently they are executed, inflict further in*jury to the epiphyseal plate Reduction, if necessary is accomplished more easily in early than late lesions and less force effects a reduction in early than in late epiphyseal separation

Lesions with slight displacement of the

Fig 253 (*Left*) Complete epiphyseal separation Several attempts at reduction by manipulative measures failed. (*Right*) Repositioned by surgical intervention of the epiphysis shown at left. Internal fixation was necessary because stability of the fragments could not be achieved otherwise.

deformity or complete displacement are reduced with the patient in a recumbent position under a general anesthesia. Shortening of the limb is overcome by traction, with the arm slightly flexed and abducted. Length having been restored the fragments are manipulated into satisfactory alignment. By releasing the traction the fragments are permitted to engage. Postreduction treatment is the same as that of fractures of this region which requires no reduction. Anatomic neck fractures occurring in conjunction with dislocation of the glenohumeral joint are discussed under fracture-dislocations.

SEPARATION OF THE HUMERAL EPIPHYSIS

Three centers of ossification—one for the head, the greater tuberosity and the lesser tuberosity—coalesce at the sixth or the seventh year to form the upper end of the humerus or upper humeral epiphysis which fuses with the shaft about the twentieth year. The epiphyseal plate is roughly concave; begins at the base of the greater tuberosity and continues upward and inward to the middle of the epiphysis, then follows the line of the anatomic neck.

FIG. 251. (*Left*) Epiphyseal fracture of the humerus with typical adduction deformity. The epiphyseal fragment includes a large triangular portion of the upper end of the diaphysis. (*Right*) Following replacement of the epiphysis shown at left.

The most common injury to the upper end of the humerus in the second decade of life is separation of the upper humeral epiphysis. The mechanism of production is similar to that of fractures of the surgical neck. In the vast majority of cases the shaft is adducted in relation to the head. Occasionally, however, an abduction type of displacement is encountered.

There may be only minimal separation of the epiphysis with little or no displacement demonstrable in the radiographic examination by widening of the epiphyseal place in the region of the base of the greater tuberosity and a slight inward tilt of the capital mass. Complete separation may occur with displacement of the diaphysis inward, upward and forward. This lesion resembles in every respect adduction fracture through the anatomic neck with complete displacement. Incomplete displacement may occur

FIG 255 (*Left*) Fracture-dislocation of the humerus. No displacement of the greater tuberosity fragment has occurred there also exists a fracture through the anatomic neck. (*Center*) Fracture-dislocation of the humerus with the greater tuberosity in approximately its normal position relative to the scapula. However the head had traveled a considerable distance from the glenoid cavity Closed methods to reduce this dislocation failed Open measures revealed the biceps tendon displaced posteriorly, obstructing replacement of the head. A vertical tear of the musculotendinous cuff was found in the interval between the subscapularis and supraspinatus muscles. (*Right*) Fracture depicted (*center*) reduced greater tuberosity fixed to the head with 1 screw The cuff was repaired.

duction in such instances is warranted In late cases, however, when great force must be employed to mobilize the fragments for repositioning, one is justified in accepting the deformity in lieu of traumatizing the epiphyseal plate and assuring subsequent bone-growth disturbance.

Complete displacement of the upper humeral epiphysis demands reduction Every attempt should be made to reduce the lesion as soon as posible after the injury Complete muscle relaxation is best attained with a general anesthesia

With the patient in the recumbent position an assistant makes slow steady traction on the abducted (from 45° to 60) and flexed arm. Moderate traction is maintained until shortening of the arm is overcome The operator then places both hands in the axilla so that the fingers are on the upper and inner end of the diaphysis and the thumbs are on the outer aspect of the capital fragment he then forces the shaft outward and backward. Traction is then released to allow engagements of the fragments Reduction is maintained best by a plaster jacket holding the arm in from 30° to 60 abduction, 30° forward flexion midway between internal and external rotation (Fig 252)

After 3 or 4 weeks the jacket is removed and the arm is brought to the side and suspended in a collar-cuff sling At the end of 2 weeks free use of the extremity is permissible As a rule, special exercises and other physical measures are not essential in the postreduction management of children.

Occasionally it is impossible to reduce the displacement or to maintain it without continuous traction. In such instances traction with the patient in bed should be employed as described for fractures of the surgical neck

Open reduction is justified when it is impossible to effect a reduction by manipula

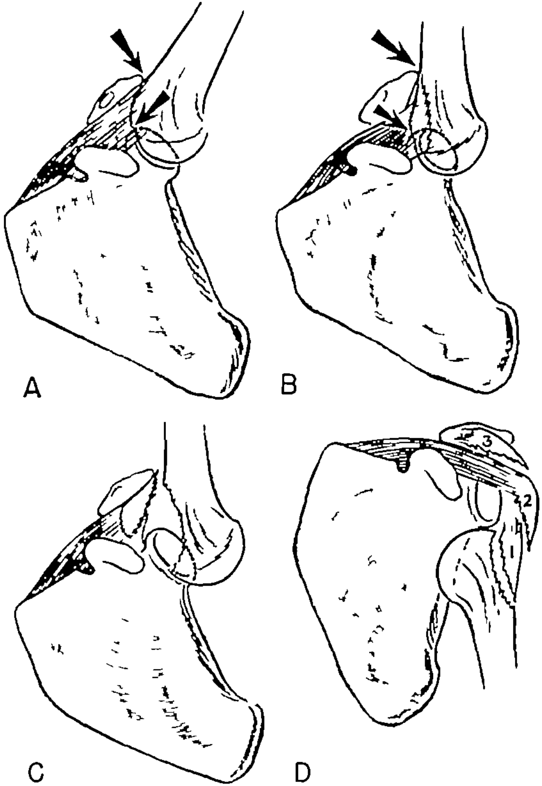

FIG 254 Mechanism of dislocation associated with fracture of the greater tuberosity The different positions in which the greater tuberosity may be found (1) the tuberosity follows the head (2) it retains its normal relation to the scapula (3) it has been retracted under the acromion.

humeral epiphysis should not be disturbed Fixation of the extremity with a collar-cuff sling and a swathe about the body affords adequate immobilization The amount of displacement does not tend to increase Thus, more rigid immobilization is not necessary There is sufficient healing to permit free use of the extremity after 3 weeks

If seen early most lesions with moderate displacement can be reduced by gentle traction and manipulative maneuvers and re-

FIG 257 (*Left*) Fracture-dislocation with impaction of the head fragment. Manipulative methods to effect reduction may disengage the fragments, thereby adding to the difficulty of reduction (*Right*) Fracture-dislocation with marked displacement of the head fragment. All nourishment to the head is severed if the head is replaced on the end of the shaft, avascular necrosis is a certainty The greater tuberosity is pulled under the acromion by the external rotators

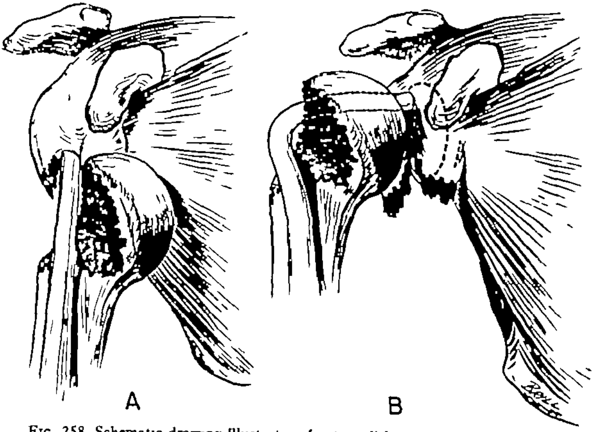

FIG 258 Schematic drawing illustrating fracture-dislocation in which the tuberosities have been pulled off the humerus and, with the cuff intact have dropped in front of glenoid cavity (A)—thereby obstructing reduction (B) The biceps tendon usually is displaced posteriorly

FIG 256 Fracture-dislocation of the humerus in which the greater tuberosity is completely displaced from its normal bony position but has followed the shaft of the humerus. In this instance the cuff may be severely stretched across the glenoid cavity or it may be ruptured.

tion or traction or when healing has progressed to the point that it is impossible to mobilize the fragments without serious damage to the epiphysis and the soft tissue structures The surgeon should be cognizant of the fact that open reduction is followed invariably by disturbance of bone growth and he should realize further that this sequela will be of less significance to the patient than the deformity of the displaced unreduced epiphysis (Fig 253)

FRACTURE DISLOCATIONS OF THE HUMERUS

Fractures of the upper end of the humerus occurring in conjunction with dislocation of the glenohumeral joint constitute the most difficult of all shoulder injuries In general two types of fractures may occur with dislocation (1) fracture of the greater tuberosity and (2) fracture of the humeral head or neck

FRACTURE OF THE GREATER TUBEROSITY

This lesion is the most common complication and occurs in from 25 to 30 per cent of all dislocations of the glenohumeral joint. Its mechanism of production denotes that it must be accompanied necessarily by extensive damage of the musculotendinous cuff (Fig 254) A rough evaluation of the soft tissue injury may be ascertained by the radiographic characteristics of the fracture

In most cases the tuberosity fragment lies in its normal anatomic position in relation to the acromion and retains its attachment to the musculotendinous cuff A tear paralleling the fibers of the cuff in the interval between the supraspinatus and the subscapularis tendons constitutes the usual soft tissue injury The humeral head is dislocated but may be within the capsule and corresponds to Codman s "false-dislocation." Reduction of the dislocation by the methods described affects anatomic repositioning of the fragments Treatment is the same as if no fracture existed Abduction splints and other appliances are not necessary and are harmful

Occasionally with the tuberosity in approximately its normal position and within the musculotendinous cuff the head may occupy a position at a great distance from its normal berth Such displacement may tear the biceps tendon from its insertion into the superior glenoid rim or displace it to a position posterior to the head In this abnormal position the tendon may act as a mechanical impediment to reduction and require operative intervention to achieve replacement of the humeral head (Fig 255)

Retraction of the fracture fragment under the acromion associated with dislocation is indicative of extensive tearing of the musculotendinous cuff Management of this lesion entails repositioning of the fragments

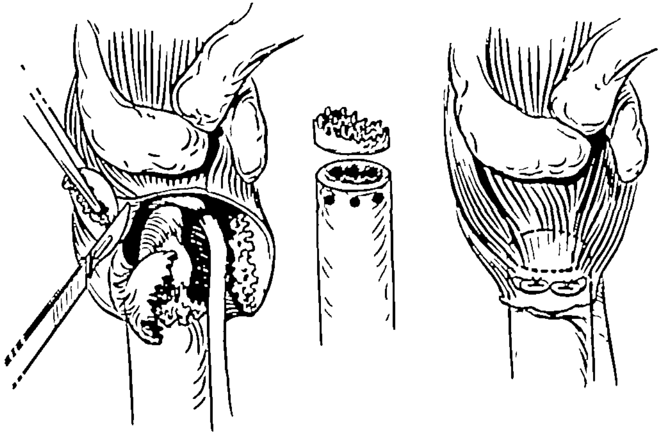

FIG 261 Operation to restore function of the rotator muscles and stability of the glenohumeral joint. The head and tuberosity fragments are removed the musculotendinous cuff and inferior capsule are sutured through drill holes made in the shaft to a lower level on the shaft of the humerus.

comprises pronounced disorganization of the osseous and soft tissue elements of the joint the jagged ends of the fragments may injure the brachial plexus and vessels in the axilla Injury to these structures may occur at the time of the initial violence or during the course of manipulative maneuvers Some workers advocate closed methods to effect reduction chiefly by application of strong traction to the abducted arm and manipulation of the head into the glenoid cavity (Figs 257 260)

It becomes evident that such procedures further jeopardize the neurovascular elements and are likely to inflict more trauma to the musculotendinous cuff Moreover any existing impaction of the fragments may be broken up thereby adding gerater difficulty to the problem of reduction Above all methods such as the Kocher or the Hippocratic which utilize the humerus as a lever should be condemned

Visualization of the pathology is the most logical approach to this difficult problem. McLaughlin s transacromial incision provides adequate exposure of the subacromial area and ample room for whatever operative work is deemed necessary

Repositioning of the fragments into normal alignment and replacement of the head in the glenoid cavity should be done with the utmost gentleness It may be necessary to divide the insertion of the pectoralis major and the subscapularis muscles to mobilize the fragments adequately Every effort should be made to preserve soft tissue and periosteal attachments of the head fragments Pieces of bone completely devoid of soft tissue should be removed The fragments after being assembled are fixed to one another by wire or stout cat gut sutures passing through drill holes in the adjacent fragments Nicola s procedure may be utilized to advantage in stabilizing the ana

FIG 259 Fracture-dislocation with wide separation of fragments. Head fragment and tuberosities were removed and the cuff was anchored to the end of the shaft of the humerus.

and repair of the disrupted cuff which can be achieved only by open methods These have been described in the discussion on fractures of the greater tuberosity with retraction

In some instances the fractured tuberosity follows the humeral head at some distance from its anatomic position in relation to the scapula (Fig 256) In such cases, one can assume that the external rotators are severely stretched over the glenoid cavity or torn from the tuberosity Following reduction the operator must be on the alert for clinical evidence of a torn cuff If such evidence is apparent, exploration of the subacromial area through a transacromial incision is justified and the torn cuff is repaired by the method already described

FRACTURES OF THE HEAD AND THE NECK OF THE HUMERUS WITH DISLOCATION

These lesions usually occur in individuals past middle life and constitute the most serious of all complications of dislocation of the glenohumeral joint The pathology

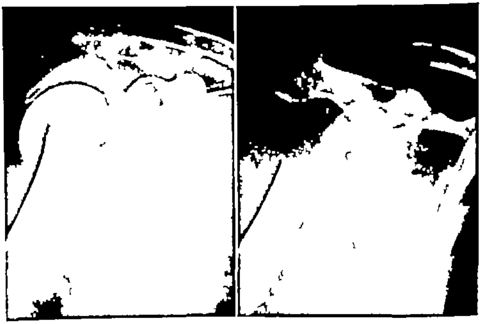

FIG 260 (*Left*) Fracture-dislocation with complete detachment and wide separation of fragments The head of humerus and the tuberosities were removed The cuff and the inferior capsule were reattached to head of shaft of humerus (*Right*) Following removal of head and tuberosities and reattachment of cuff and capsule to end of shaft of patient shown at left.

and performed in the splint which is worn continuously for 4 weeks and at night for 2 additional weeks

The results of this procedure have proven to be highly satisfactory in the hands of some workers However the author has found McLaughlin s operation to be more satisfactory

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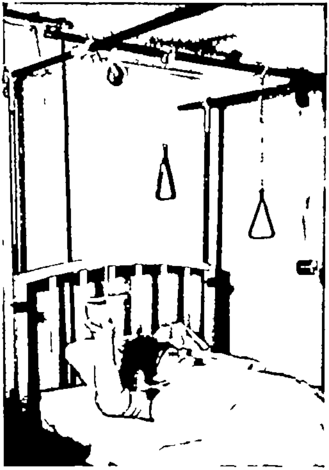

FIG 262 Patient of Figure 260 following operation with arm in balanced suspension allowing early active motion and development of tone and control in muscles of the shoulder girdle

tomic head on the shaft Repair of the cuff tears usually ensures maintenance of reduction of the fragments

Not infrequently the anatomic head is found lying free in the soft tissues completely severed from any source of nourishment or comminution is so great that avascular necrosis is a certainty In such instances removal of the head fragment is unavoidable despite the realization that the procedure causes great functional disability Without the humeral head the short rotators are no longer able to stabilize the humerus on the glenoid cavity making elevation of the arm impossible

Several ingenious procedures have been designed to overcome this mechanical disadvantage. McLaughlin advocates transplantation of the insertion of the musculotendinous cuff to a lower level on the humeral shaft and reconstruction of the disrupted cuff so that, with the inferior portions of the fibrous capsule, it surrounds the upper end of the humerus completely He further recommends removal of the outer half of the acromion and suturing the central tendon more mesially in order to increase the leverage power of this muscle for the elevation of the extremity The author has performed this operation many times and found it to be most satisfactory (Fig 261)

Postoperative management should aim at mobilization of the extremity as soon as sufficient soft tissue healing permits The arm is placed in balanced suspension (Fig 262), and motion is started immediately After from 10 to 12 days the arm is brought to the side and stooping exercises are begun A rigid regimen of progressive exercises must be enforced to develop the muscle tone and control necessary to stabilize the new glenohumeral articulation

Lawrence Jones has devised a procedure similar in principle to the one just described. The subacromial area is exposed by a Cubbins incision (see Operative Approaches to the Shoulder Joint) and the musculotendinous cuff is freed from bony attachments All fragments of the upper end of the humerus are removed and the end of the shaft is rounded Two flaps are created from the musculotendinous cuff an anterior flap comprising the subscapularis muscle, and the posterior flap consisting of the supraspinatus the infraspinatus and the teres minor muscles. Approximately 2 inches below the rounded end of the humerus two vertical grooves are made in the humeral shaft through the entire thickness of the cortical bone The flaps are sutured in their respective grooves and to one another by a strip of fascia lata previously obtained from the thigh

Postoperative treatment entails fixation of the extremity in 135 abduction by means of an abduction splint Exercises are begun as soon as soft tissue healing is complete

and performed in the plint which is worn continuously for 4 weeks and at night for 2 additional weeks

The results of this procedure have proven to be highly satisfactory in the hands of some workers However, the author has found McLaughlin s operation to be more satisfactory

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9

Shoulder Pain of Neurogenic Origin and Obstetric Paralysis

INTRODUCTION

Pain projected to the shoulder and the arm may be produced by a host of etiologic factors Failure to apprehend the cause and the mechanism of the pain has favored the adoption of such vague nonspecific terms as brachial neuritis and brachialgia Nachlas however emphasizes that brachialgia is a symptom complex characterized by pain radiating to the shoulder and the arm and in no way denotes a causative agent

This observer also points out that the syndrome may result from irritation of sensory nerve fibers from the sensorium to the peripheral point of reference Accumulated knowledge of this problem and more adequate comprehension of the mechanisms of the heterogeneous causative factors reveal that in the vast majority of instances the syndrome is produced by compression of the spinal cord (spinal cord tumors) or nerve roots (herniated intervertebral disks), lesions which are amenable to treatment usually followed by gratifying results.

Clinical and experimental investigations disclose that segmental reference of pain to the shoulder region and the arm does not always result from sensory nerve involvement of the central or peripheral nervous system it may be produced by pathologic processes affecting such tissues of mesodermal origins as ligaments periosteum, fascia tendons and muscles. Moreover it is generally known that disorders of the heart lungs great vessels pleura diaphragm and even abdominal viscera may give rise to the same syndrome

Thus, the numerous causative factors can be *grouped into two categories* (1) those of neurogenic origin and (2) those of non neurogenic origin

Lesions of neurogenic origin are characterized by such objective manifestations of central and peripheral nerve involvement as wasting and motor weakness of muscles abnormal reflex reactions fibrillations sensory alterations adhering more or less to a segmental pattern and finally distinctive features of pain which will be considered subsequently

REFERRED PAIN

Lewis and Kellgren were able to produce pain identical to that of angina pectoris by injecting the left eighth cervical or the first dorsal interspinous ligament with 5 per cent saline solution The induced pain produced the same segmental pattern as angina pectoris In some instances numbness and tingling of the hands as well as hyperalgesia of the skin along the inner aspect of the arm were also concomitant features The e investigators have demonstrated that muscular rigidity and deep tenderness in addition to segmental pain can be produced by stimulating somatic structures and viscera Eaton points out however that hyperalgesia and paresthesias evoked by somatic and visceral stimulation usually indicate pathologic disorders of the central or peripheral nervous system

Kellgren noted that by injecting a specific muscle he provoked pain in a definite area, following a segmental pattern The pain distribution in a given segment was generally constant, unless it was of unusual severity then it spread to other segments

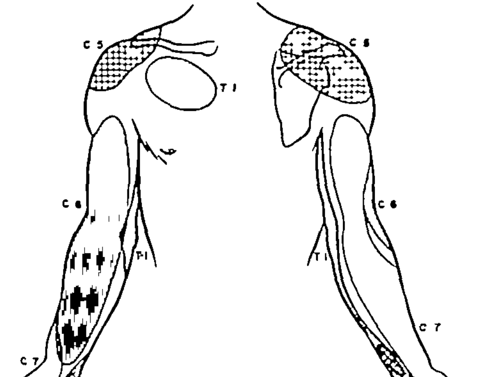


Fig 263 Distribution of pain following injection of rhomboids (horizontal square hatching) flexor carpi radialis (vertical hatching) abductor pollicus longus (light stippling) third dorsal interosseous (oblique square hatching) and first intercostal muscle (dark stippling) (Kellgren Clin. Sc. 3 183 Redrawn with modifications.)

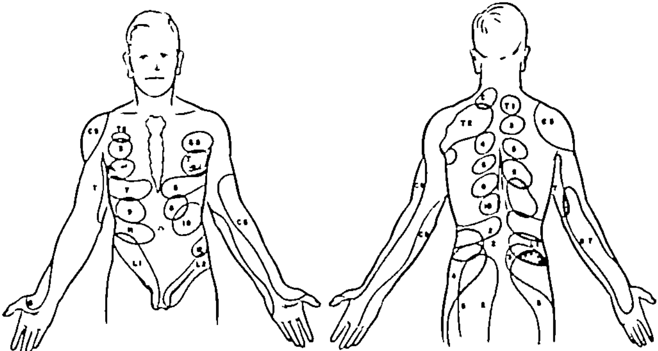


FIG 264 Segmental areas of deep pain developed by the injection of the corresponding interspinous ligaments (diagrams constructed from Kellgren) (Lewis Pain Macmillan p 123 Redrawn with modifications.)

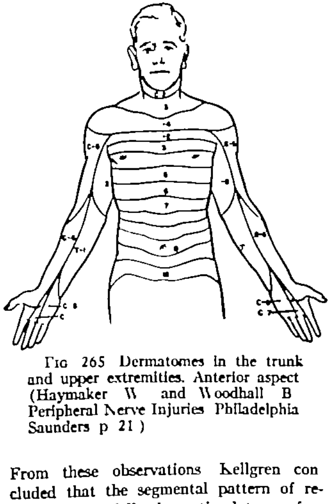


FIG 265 Dermatomes in the trunk and upper extremities. Anterior aspect (Haymaker W and Woodhall B Peripheral Nerve Injuries Philadelphia Saunders p 21)

From these observations Kellgren concluded that the segmental pattern of referred pain following stimulation of a muscle is determined by the nerve root or roots supplying the muscle The pattern will include other muscles supplied by the same nerve root or roots.

For example, the ninth intercostal nerve supplies the multifidus, the rectus and the intercostal muscles By injecting any one of these muscles with hypertonic saline solution, Kellgren could evoke pain in all three areas Moreover by injecting the interspinous ligaments of the vertebral column at each segmental level, he induced pain in the extremities and the trunk and the pain followed a specific segmental pattern no different from that obtained by stimulating the individual muscles supplied by the same spinal segments (Figs 263 and 264)

Deep segmental pain according to the above investigators, is independent of the superficial or cutaneous form described by Foerster and by Head Their segmental pattern is similar but discloses some differences particularly in the extremities Segmental sensory areas of the superficial system were designated dermatomes" by Head and skin areas' by Sherrington. Dermatomes extend to a lower level in the extremities than the pattern of deep segmental pain (compare Figures 265 266 and 267 with Figure 264)

Inman and Saunders have made some significant observations referable to deep pain when mesodermal tissues were stimulated by *chemical or mechanical agents* Deep radiating pain was produced by stimulating periosteum fascia bones ligaments and tendons This pain was segmental in nature and unrelated to the peripheral sensory nerves or their segmental cutaneous distribution The investigators postulate that this type of deep pain may originate in fine sensory nerve endings located in the deep structures *and that local axon reflex or mi*interpretation by the central nervous system may be responsible for the radiation Inman and Saunders contend that irritation of deep mesodermal tissues produces deep radiating pain whose pathways correspond to the segmental innervation of the periosteum ligaments and attachments of muscles also that these pathways are continuous *and extend the entire length of the* limb They designated these deep segmental areas as "sclerotomes"

Dermatomal patterns of cutaneous distribution differ from those of scleratomes The former are located on the preaxial and the postaxial borders of the extremity whereas as previously noted the latter extend distally for almost the entire length of the limb However a dermatome may overlie a limited segment of the corresponding sclera tome Pain produced by irritation of deep mesodermal tissue is deep dull and boring in nature there is no evidence of cutaneous sensory disturbances muscular weakness or atrophy or abnormal reflex phenomena

The experiments of both Lewis and Kellgren and Inman and Saunders reveal that irritation of mesodermal structure is accompanied by muscle soreness and rigidity and *tenderness* over ligaments and bony prominences in the pathways of deep radiation It is apparent that tenderness may b

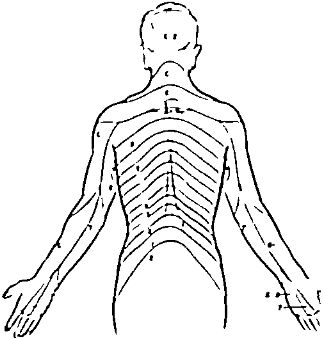


FIG 266 Dermatomes in the trunk and upper extremities. Posterior aspect. (Haymaker and Woodhall Peripheral Nerve Injuries, Philadelphia, Saunders p 19)

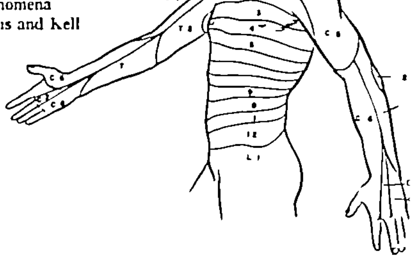
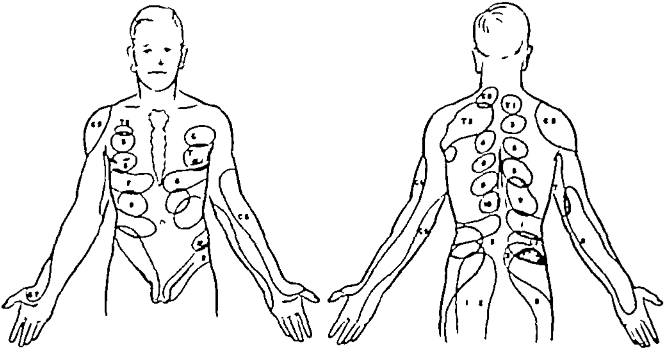


FIG 267 Dermatomes in the trunk and upper extremities. Lateral aspect. (Haymaker and Woodhall Peripheral Nerve Injuries Philadelphia, Saunders p 20)



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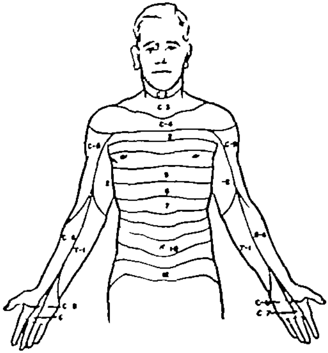

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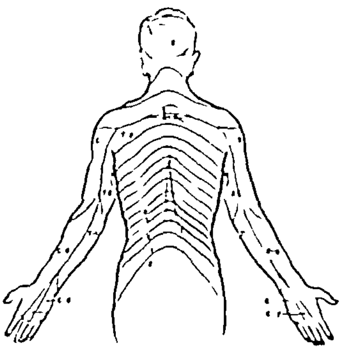

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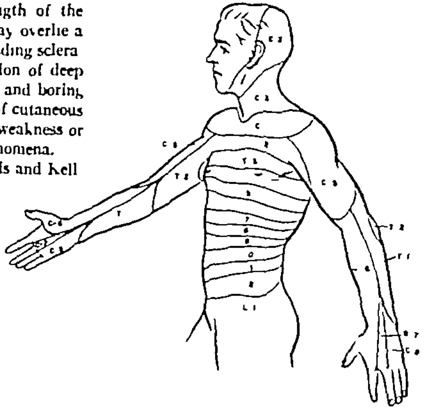

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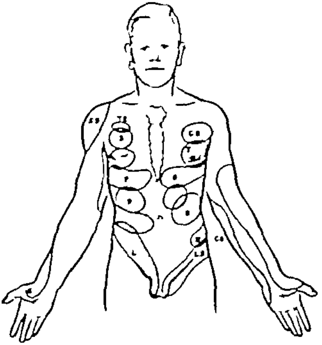

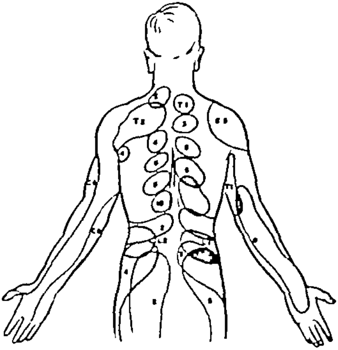

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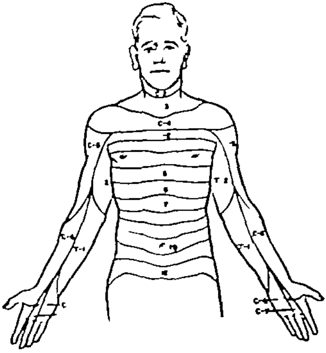

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roots. These areas (designated dermatome) provide a useful guide in determining the nerve root responsible for pain in a specific area of the extremity (Figs. 265, 266 and 267).

In the extremities, in contrast with the trunk, there is considerable overlap of cutaneous distribution of the individual root. This adds some difficulty in identifying the precise root affected. Diagnostic difficulties may be further increased by pain in only a small part of a specific dermatome. Eaton explains this by the theory of incomplete involvement of the nerve root. Theoretically pain is referred to the entire cutaneous distribution of a nerve root when all the sensory fibers comprising the root are stimulated. However, if only a few of the fibers are involved, pain is projected only to that portion of the dermatome supplied by the affected sensory fiber.

This mechanism affords an explanation for the presence of isolated localized areas of pain in the shoulder region, the arm or the fingers resulting from compression of a sensory nerve root by protrusion of a disk in the cervical region. For example, in one patient with a protrusion of a disk between the fifth and the sixth cervical vertebrae which was proved subsequently, the syndrome was initiated by excruciating pain in the index finger with no other objective or subjective sensory manifestation.

Eaton cites two other features peculiar to radicular pain: (1) increased intra-abdominal or intrathoracic pressure tends to intensify or reproduce the pain and (2) stretching of an affected root accentuates the pain.

The investigator demonstrated by clinical experiments that increased intra-abdominal and intrathoracic pressure resulting from such acts as sneezing, coughing and straining produces distention of the epidural veins lying in loose areolar tissues in the epidural space between the dura mater and the spinal canal, consisting of the vertebral osseous elements, the intervertebral disks and the connecting spinal ligaments. The epidural veins are continuous with intervertebral

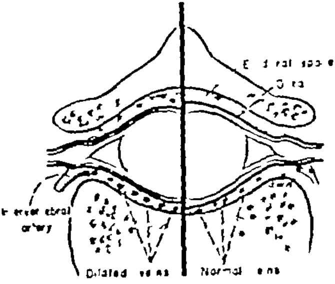

Fig. 268. Cross section of the spinal cord, dura and epidural space during straining maneuvers on the left and before straining on the right. (Modified from Eaton, L. M.: J.A.M.A. 117:1435.)

veins which in turn flow into the abdominal and the thoracic vein. It is obvious that collapse or even compression of these large veins by increased intra-abdominal or intrathoracic pressure will cause engorgement of the epidural veins.

According to Eaton, this distention results in displacing the dura toward the spinal cord, thereby making traction on the nerve root. This observer does not believe that traction or compression of normal nerve roots by the distended epidural veins can produce pain, although traction on traumatized or diseased roots may evoke radiating pain. He further demonstrated that increased pressure in the cerebrospinal fluid plays no part in the production or the accentuation of root pain (Fig. 265).

Acts which tend to stretch injured nerve roots usually reproduce or intensify radicular pain. Eaton points out that the nerve roots are firmly fixed peripherally after they emerge from the intervertebral foramina. During maneuvers such as bending of the head far forward, forward bending of the trunk with knees extended, and Lasègue's maneuver (with the thigh flexed on the abdomen, the leg is extended), the nerve roots are stretched. While no pain is elicited under normal conditions, stretching of trau

an associated phenomenon of referred pain and is not always indicative of a pathologic process in the underlying tissues

Pain and tenderness at the deltoid tuberosity and in the deltoid muscle are common findings in such disorders involving the supraspinatus region of the musculotendinous cuff as calcareous tendinitis and tears of the cuff Lesions involving the biceps tendon (bicipital tenosynovitis) are characterized by pain projected to the belly of the biceps brachii muscle and by tenderness and soreness discernible by palpation and pressure

It becomes obvious from the aforementioned experimental and clinical data that false localization of pain in the shoulder region may result from irritation of distant mesodermal tissues innervated by the same spinal segments as the areas to which the pain is projected As demonstrated by Kellgren injection of the fifth cervical interspinous ligament innervated by the fifth cervical nerve produced pain in the region of the deltoid supplied by the same nerve Shoulder and arm pain associated with diseases of the heart and the gallbladder is common knowledge

Kellgren and Lewis have produced pain which exhibits a segmental pattern and is associated simultaneously with cutaneous deep tenderness and muscle rigidity by stimulating somatic structures Such phenomena resemble closely those produced by stimulation or diseases of the viscera The observers are of the opinion that the objective manifestations of both somatic and visceral stimulation are indistinguishable Lewis records "a manifest and simple explanation for these remarkable resemblances which include the pain phenomena and the associated rigidities and tenderness is the existence of a common though complex mechanism which is stirred into activity by afferent impulses derived from either deep-lying somatic structures or from disturbances of a viscus

Although the mechanism of pain referred from somatic structures or viscera is still obscure and the source of much controversy and conjecture and in spite of the fact that such pain is not pathognomonic of any specific lesion the characteristics of the pain may provide helpful diagnostic clues.

Skin and deep pain possess distinguishing features clinical and experimental data lead one to conclude that they are two distinct forms of sensation (Lewis) Cutaneous pain is characterized by quick reflex phenomena either fleeting or prolonged, of rather even intensity, depending upon the type of stimulation and accurately localized to specific areas Deep pain originating from muscle fascia and periosteum is best described as being dull and boring It is rather diffuse in nature and difficult to localize to a specific region It is often associated with sweating nausea vomiting drop in blood pressure if the pain is of great intensity, the patient may even collapse Patients often refer to this vasovagal phenomenon as sickening The above features never are associated with pain of cutaneous origin Some observers believe that the diffuse character of the pain is the result of intrasegmental diffusion the extent of area involved depending upon the intensity of the pain

Inman and Saunders postulate that "lesions of mesodermal structures bring about through some obscure reflex mechanism, radiation of pain along the pathways corresponding to the approximate segmental innervation of the periosteum ligamentous structures and attachments of muscles.

As previously noted these pathways were designated scleratomes and are in no way related to the dermatomes of peripheral nerves

Pain is often projected to the region of the shoulder and the arm by compression of one of the cervical sensory nerve roots. Radicular or root pain exhibits characteristic features which are helpful diagnostic aids Pain is referred to the cutaneous area supplied by the affected root thereby disclosing a definite segmental pattern Sherrington and more recently Foerster have deciphered and charted the cutaneous pattern of distribution of the sensory nerve

provide a bony enclosure (spinal canal) for the 8 cervical segments and a portion of the first thoracic segment of the spinal cord. No disk exists between the occiput and the atlas or between the atlas and the axis. The first cervical disk is situated between the second and the third cervical vertebrae. Only a small exit is found for emergence of the second cervical root between the atlas and the axis. Only 6 well formed bony foramina are demonstrable in the cervical region. The first is situated between the second and the third cervical vertebrae. The first cervical nerve takes its exit between the occiput and the atlas.

It is obvious that confusion may arise in referring to specific levels in the cervical region. For example, the fourth disk is located between the fifth and the sixth cervical vertebrae, which form the fourth intervertebral foramina, which in turn is traversed by the sixth cervical nerve. Figure 270 discloses that the cervical nerves emerge from intervertebral foramina above their respective vertebrae. For example, the sixth cervical nerve traverses the foramen above the sixth cervical vertebra. To avoid confusion in referring to lesions of the intervertebral disks, it is best to designate the specific nerve involved or to identify the disk by naming the specific vertebrae above and below, for example, the intervertebral disk between the fifth and the sixth cervical vertebrae.

As mentioned above, there are 6 intervertebral foramina from which emerge the last six cervical nerves. Each foramen is ovoid in shape, with a large vertical and a smaller horizontal diameter. Ample room is provided for the cervical nerve roots, which occupy roughly half of the available space in the foramen. This last anatomic feature is of special clinical significance. Some observers maintain that narrowing of the intervertebral disk is followed by hypertrophic arthritis, that narrowing of the intervertebral disk may reduce the height of the vertical diameter of the foramen and compress the nerve roots (Turner and Oppenheimer).

According to Semmes and Murphey, narrowing of the foramen subsequent to thinning of the intervertebral disk does not cause nerve root pressure. They contend that even with total obliteration of the intervertebral disk space the foramen is spacious enough to accommodate the cervical nerve and root without causing pressure. However, destruction of adjacent surfaces of the vertebrae, in addition to thinning of the intervertebral disk, may narrow the vertical diameter of the foramen sufficiently to cause pressure on the nerve root. Lesions which reduce the horizontal diameter of the foramina are more apt to cause compression of the nerve root. This explains the compression syndrome that may ensue when a small lateral protrusion of the intervertebral disk occurs. Although there is evidence substantiating the observation that hypertrophic arthritis per se is not apt to reduce the size of the foramina sufficiently to produce radicular pain, one must realize that associated inflammatory processes (affecting the ligamentous structures and the capsular tissues surrounding the foramen) may reduce the lumen of the foramen sufficiently to cause nerve root pressure.

Moreover, in the light of the work of Kellgren, radicular pain to the shoulder and the arm may result from irritation of the deep ligaments and the capsular tissues in the cervical region by a process such as hypertrophic arthritis. He was able to produce segmental pain in the arm by stimulating the sixth and the seventh interspinous ligaments.

The seven cervical vertebrae form a smooth lordatic curve, whose apex is roughly at the fifth or the sixth vertebra. At the apex of the curve, the intervertebral foramina (those between the fifth and the sixth and the sixth and the seventh vertebrae) are narrower than those above and below (Semmes and Murphey). The two intervertebral disks above—particularly the one between the sixth and the seventh cervical vertebrae—are vulnerable to stress and strains because of their greater mobility

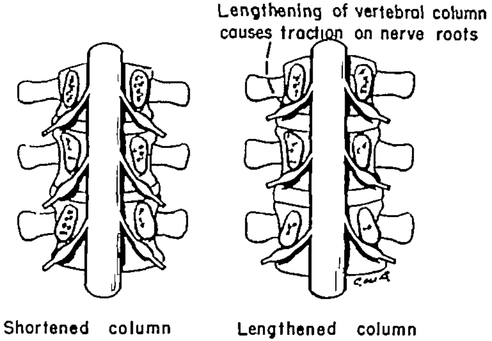

FIG 269 Diagram showing effect of lengthening of the vertebral column on the nerve roots. Note that the spinal cord and the nerve roots are stretched.

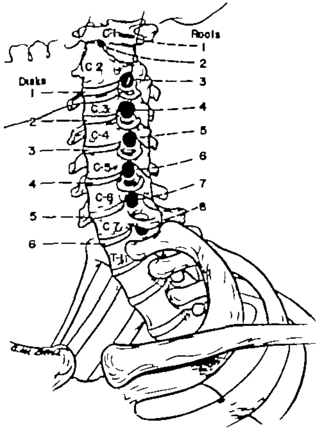

FIG 270 Tracing made from a roentgenogram of the cervical and upper thoracic spine showing the intervertebral foramina, intervertebral disks and vertebral bodies.

matized nerve roots causes or accentuates radicular pain Often root pain is reproduced or intensified during sleep and is relieved on getting out of bed

Eaton contends that the weight of the body in an upright position compresses the intervertebral disks, thereby reducing the height of the spinal column—as compared with its length in the horizontal position during sleep In the latter position the increased length is secondary to the increase in the vertical height of the intervertebral disks that occurs when the disks are relieved of the weight of the body The increase in length of the spinal column stretches the spinal cord and the nerve roots. Under normal conditions such increased tension in the cord and the roots is within normal physiologic limits and produces no pain however stretching of diseased or traumatized roots may provoke or accentuate radicular pain (Fig 269)

ANATOMIC CONSIDERATIONS

Cervical Segment of the Spinal Column

This segment comprises 7 cervical vertebrae and 6 intervertebral disks which

cervical and first thoracic nerves. The seventh cervical nerve supplies the axis of the limb but also provides sensory nerve fibers which innervate such deep structures as periosteum, ligaments and muscles.

Variations of the spinal segments comprising the brachial plexus are encountered, the most common being designated the prefixed and the postfixed plexuses. In a prefixed plexus the entire plexus is at a higher level; a large portion of the anterior primary ramus of the fourth cervical nerve goes into its formation but receives few fibers from the first thoracic nerve. A postfixed plexus occupies a lower level. It receives a large contribution from the anterior primary ramus of the second thoracic nerve but receives no fibers from the fourth and only a few from the fifth cervical nerves.

As will be shown subsequently, both prefixed and postfixed plexuses are at times responsible for radiating pain in the shoulder and the arm, especially if such anomalies of the thoracic outlet exist as a cervical rib or abnormal first thoracic rib. As previously recorded, the cutaneous distribution of the sensory fibers of a spinal nerve exhibits a segmental pattern designated dermatome. There is, however, great overlapping of the adjacent dermatomes and it may be impossible to identify the sensory root affected by abnormal sensory manifestations in a specific area.

Ordinarily the anterior primary rami of the fifth and the sixth cervical nerves form the upper trunk; that of the seventh continues as the middle trunk, while the rami of the eighth cervical and first thoracic nerves constitute the lower trunk. Each trunk divides into an anterior and a posterior division from which are derived the three cords of the brachial plexus. The lateral cord consists of the anterior divisions of the upper and the middle trunk; the posterior cord embodies the posterior division of all three trunks, and the anterior division of the lower trunk continues as the medial cord. From the three cords arise the major peripheral nerves of the upper extremity.

The lateral cord gives origin to the musculocutaneous nerve and the lateral head of the median nerve, also to the lateral anterior thoracic nerve. The posterior cord gives origin to the axillary and the radial nerves and to the two subscapular and the thoracodorsal nerve. From the medial cord are derived the medial head of the median nerve and the ulnar nerve, also the medial anterior thoracic nerve and the medial cutaneous nerves of the forearm and the arm (Fig. 271). Rearrangement of the nerve fibers comprising the brachial plexus takes place in the divisions of the plexus. In general those fibers which will supply the ventral parts of the extremity reach their destination through the anterior divisions and those supplying the dorsal parts through the posterior divisions. Table 2 gives the segmental supply of the skeletal muscles of the neck, the shoulder and the upper arm. Figures 265, 266 and 267 depict the segmental pattern of sensory supply of the skin of the upper limbs and the upper portion of the trunk.

Sympathetic innervation to the upper extremity arises in the lateral horn cells of the spinal segments T-3 to T-6 inclusive. Some investigators believe that T-2 and T-7 may also contribute fibers to the brachial plexus. Preganglionic fibers which arise in the above spinal segments leave the spinal cord via the corresponding anterior roots, traverse the primary anterior rami and reach the thoracic sympathetic chain as white rami communicantes. They then ascend to the stellate and middle cervical ganglia where they synapse with postganglionic fibers. The postganglionic fibers as gray rami communicantes reach the anterior primary rami of the brachial plexus and then the periphery via the peripheral nerves. They supply the blood vessels, the sweat glands and the pilo-erector muscles (Fig. 272).

The preganglionic fibers destined to innervate the ocular structures traverse the primary rami of T-1 and T-2 and possibly T-3. They enter the sympathetic chain via

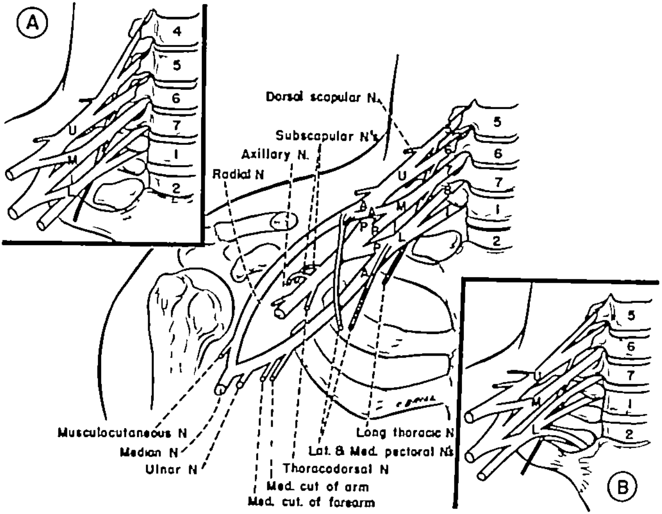

FIG 271 Brachial plexus and the most common variations (A) Prefixed plexus. (B) Postfixed plexus. (Haymaker and Woodhall Peripheral Nerve Injuries Philadelphia, Saunders p 129 Redrawn with supplementations.)

and because they comprise the transitional area between the freely movable upper cervical spine and the fixed thoracic spine (Bradford and Spurling) Because of the afore mentioned anatomic features and the functional demands made on this lower cervical region it is the most frequent site of pathologic disorders especially those of mechanical nature Degeneration with or without protrusion of the disks between the fifth and the sixth and the sixth and the seventh cervical vertebrae are common lesions

Brachial Plexus

Spinal nerves supplying the extremities differ from those supplying the trunk in that they form plexuses. In the early development of the upper extremities a specific number of metameres migrated distally to form the limb buds The respective spinal nerves grow into the limb bud their anterior primary rami form plexuses in which the nerve fibers are grouped so that the upper spinal nerves of the plexus supply the preaxial border of the limb and the lower spinal nerves supply the postaxial border The central portion of the plexus is carried distally the full length of the limb and supplies the axis of the extremity

The brachial plexus comprises the anterior primary rami of the fifth, sixth, seventh and eighth cervical and the first thoracic nerves In accordance with the afore mentioned scheme the preaxial or radial surface of the limb is supplied by the fifth and the sixth cervical nerves and the postaxial or ulnar surface by the eighth

the white rami communicantes and then extend upward through the cervical ganglia to reach the superior ganglion where they synapse with postganglionic fibers which reach the ocular arteries Walshe Jackson and Wyburn Mason point out that "the only situation in which the sympathetic fibers to head, neck, forequarter and upper limbs are gathered together and capable of simultaneous involvement by a single lesion is in the stellate ganglion"

TOPOGRAPHIC AND VARIATIONAL ANATOMY OF THE SUPRACLAVICULAR REGION

A knowledge of the topographic anatomy of the components of the brachial plexuses and of the variational anatomy of this region is essential to understand the mechanism of the different compression syndromes described All have in common pain projected to the shoulder region and the arm The undivided primary anterior rami take their exit from the intervertebral foramina and traverse grooves directed downward and laterally in the anterosuperior surface of the transverse processes of the cervical vertebrae In its respective groove each root lies directly behind a slip of origin of the scalenus anticus muscle which arises from the anterior tip of the transverse process above For example the root of the fourth cervical nerve is situated between the slip of origin of the scalenus muscle from the tip of the transverse process of the third cervical and the groove in which it lies in the transverse process of the fourth cervical Thus the cervical nerve roots may be compressed by the slip of scalenus anticus muscle (Swank and Simeone)

The scalenus medius muscle lies behind the cervical roots It arises from the posterior tubercle of the transverse processes of the *second to the sixth cervical vertebrae* Both anticus and medius scalene muscles *insert into* the first thoracic rib Between them lies the subclavian artery and the roots of the brachial plexus whose lower elements are situated immediately above the

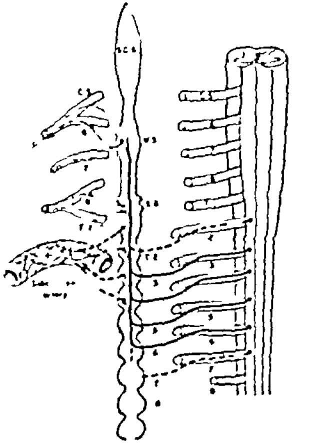

FIG. 272 Diagrammatic representation of the sympathetic innervation of the upper extremity Preganglionic fibers take origin from spinal segments T_3 to T_4 (solid lines) and perhaps from T_5 to T (dotted lines) At the point of emergence from anterior primary rami they form white rami communicantes. Postganglionic neurons (indicated by broken lines) extend to components of the brachial plexus and to the subclavian artery as gray rami communicantes S C G superior cervical sympathetic ganglion, M G middle cervical sympathetic ganglion S G stellate ganglion. (Haymaker and Woodhall Peripheral Nerve Injuries Philadelphia Saunders p 11)

artery According to Swank and Simeone the lower portions of *the two muscles* are relatively rigid and inelastic by virtue of their attachment to the first rib'

This fixed position may be increased by a *prominent* seventh cervical transverse process or a cervical rib It is conceivable from the above topographic anatomy that both upper and lower cervical *roots* are vulnerable to compression by *hypertrophy* or spasticity of the scalene muscles Swank

<table>
<tr><th colspan="18">SPINAL SEGMENTS</th></tr>
<tr><th colspan="2">C1</th><th colspan="2">C2</th><th colspan="2">C3</th><th colspan="2">C4</th><th colspan="2">C5</th><th colspan="2">C6</th><th colspan="2">C7</th><th colspan="2">C8</th><th colspan="2">T1</th></tr>
<tr><td colspan="8">Sternomastoid</td><td colspan="10"></td></tr>
<tr><td colspan="2"></td><td colspan="6">Trapezius</td><td colspan="10"></td></tr>
<tr><td colspan="4"></td><td colspan="6">Levator scapulae</td><td colspan="8"></td></tr>
<tr><td colspan="6"></td><td colspan="4">Teres minor</td><td colspan="8"></td></tr>
<tr><td colspan="7"></td><td colspan="3">Supra-spinatus</td><td colspan="8"></td></tr>
<tr><td colspan="7"></td><td colspan="3">Rhomboids</td><td colspan="8"></td></tr>
<tr><td colspan="7"></td><td colspan="4">Infraspinatus</td><td colspan="7"></td></tr>
<tr><td colspan="8"></td><td colspan="3">Deltoid</td><td colspan="7"></td></tr>
<tr><td colspan="8"></td><td colspan="4">Teres major</td><td colspan="6"></td></tr>
<tr><td colspan="8"></td><td colspan="4">Biceps</td><td colspan="6"></td></tr>
<tr><td colspan="8"></td><td colspan="4">Brachialis</td><td colspan="6"></td></tr>
<tr><td colspan="8"></td><td colspan="6">Serratus anterior</td><td colspan="4"></td></tr>
<tr><td colspan="8"></td><td colspan="8">Subscapularis</td><td colspan="2"></td></tr>
<tr><td colspan="8"></td><td colspan="10">Pectoralis major</td></tr>
<tr><td colspan="10"></td><td colspan="6">Pectoralis minor</td><td colspan="2"></td></tr>
<tr><td colspan="11"></td><td colspan="3">Coraco-brachialis</td><td colspan="4"></td></tr>
<tr><td colspan="11"></td><td colspan="5">Latissimus dorsi</td><td colspan="2"></td></tr>
<tr><td colspan="12"></td><td colspan="4">Anconeus</td><td colspan="2"></td></tr>
<tr><td colspan="12"></td><td colspan="5">Triceps</td><td colspan="1"></td></tr>
</table>

TABLE 2 Segmental supply of skeletal muscles of neck, shoulder and upper arm. The asterisks indicate a supply also from the accessory nerve. A line bisecting segment indicates that the muscle received a minor innervation from the segment. (Haymaker and Woodhall Peripheral Nerve Injuries, Philadelphia, Saunders p 26—Modification of Bing)

slightly forward but are restrained by the insertion of the scalenus anticus muscle, which prevents the neurovascular bundle from rolling forward (Fig 273)

As the subclavian artery and the trunks of the plexus continue laterally and downward they come to lie between the clavicle and the first thoracic rib At the lateral border of the first rib the subclavian artery becomes the axillary artery and it together with the three cords passes posterior to the pectoralis minor muscle just below the coracoid process.

Numerous bony abnormalities occur in the region of the thoracic operculum which may be responsible for compression syndromes. Walshe Jackson and Wyburn Mason believe that the clavicle and the abnormal rib either of cervical or thoracic origin form a vise in which the subclavian vessels and trunks of the plexus are compressed repeatedly

Lesions of neurogenic origin responsible for pain in the neck the shoulder and the arm are best grouped into three categories

1 Lesions situated within spinal cord and spinal canal

2 Lesions associated with pathologic disorders of the vertebral column

3 Lesions situated outside the vertebral column

The important lesions situated within the spinal cord and the spinal canal to be considered in this group are

1 *Neoplasms of the cervical spinal cord and nerve roots*

2 Syringomyelia

3 Hypertrophic cervical pachymeningitis

4 Platybasia

5 Herpes zoster

6 Inflammatory lesions

Neoplasms within the spinal canal may be situated extradurally or intradurally, the latter group may be subdivided into intramedullary and extramedullary tumors According to Davis 75 per cent of all spinal cord tumors are extramedullary and 75 per cent of these are intradural The subjective and the objective neurologic features and the clinical course depend upon the size and the location of the tumor

Intramedullary tumors of the cervical segments of the spinal cords are relatively rare when present pain may be referred to the shoulders and the upper extremities and it points to involvement of the sensory tracts in this region As a rule pain in central lesions is wide-spread and projected to greater areas as to the trunk and even to the lower extremities The central location of the lesion may be further disclosed by the presence of muscular weakness spasticity hyperactive tendon reflexes and extensor plantar phenomena (*Babinski*)—all indicating involvement of the pyramidal tracts Altered sensory phenomena such as loss of pain and temperature sense disclosing *involvement of the* spinothalamic pathways and impairment of position and vibratory sense pointing to damage to the posterior columns are all supportive evidence of an intramedullary lesion

Extramedullary but intraspinal tumors frequently give rise to radicular pain referred to the shoulder and the arm This is especially true of lesions below the fourth cervical segment They arise from the coverings of the spinal nerves and cord are usually discrete encapsulated tumors which are readily accessible and as a rule their removal is followed by gratifying results Radicular pain projected to the shoulder or the arm without the neurologic manifestations may be the only symptom of extramedullary neoplasm in the cervical spinal cord or nerve roots

Eaton records three characteristics of radicular pain which are helpful in differential diagnosis. The *first and most significant* is its segmental nature In involvement of the eighth cervical nerve root pain is referred to inner side of the arm the forearm the hand and the fifth finger and occasionally to the fourth and the fifth fingers Involvement of the seventh nerve root projects pain to the index finger and at times to the third finger and the thumb while involvement of the fifth and the sixth nerve

and Simeone have described two scalenus anticus syndromes superior and inferior types depending upon the level of the plexuses affected

The elements of the brachial plexus distal to the scalene muscles and occupying the supraclavicular fossa comprise the trunks The divisions lie behind the middle third of the clavicle and the cords are located in the axilla commencing just beyond the outer border of the first thoracic rib The first thoracic nerve root and, at times, the second (particularly when a postfixed plexus is present) must arch upward and over the first thoracic rib to reach the next higher root. It is situated just lateral to and slightly above the subclavian artery, which separates the nerve root from the posterior border of the scalenus anticus muscle. Both artery and plexus tend to be directed

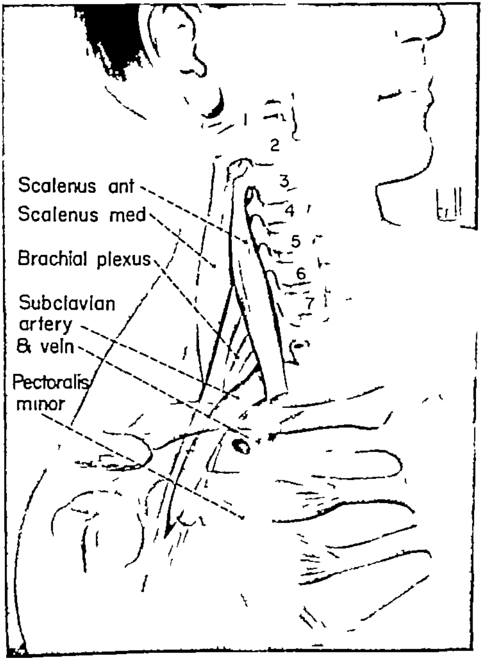

FIG 273 Drawing of anatomic specimen showing the topographic anatomy of the brachial plexus and the large vessels—particularly in relation to the first thoracic rib and clavicle the scalenus anticus muscle and pectoralis minor muscle and the coracoid process.

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roots is responsible for pain in the shoulder and outer (radial) aspects of the forearm and the thumb and frequently the index finger The second characteristic is accentuation of the pain by increased intrathoracic and such intra abdominal tension as is produced by coughing sneezing and straining (The mechanism of this phenomenon has been described previously)

Finally the third is increase in the intensity of radicular pain by maneuvers which stretch the affected nerve roots, such as flexing the head until the chin rests on the chest wall or downward traction on the arm This explains the severe nocturnal pain in these cases due to elongation of the spinal column when in a horizontal position, thereby stretching the involved nerve root Relief from pain is attained by assuming an upright position The root pain may be dull and constant in nature but more often it is sudden sharp and lancinating It may be accentuated or reproduced by certain motions of the spinal column

With increase in the size of the tumor pressure may be made on the spinal cords resulting in involvement of the sensory and the motor pathways and producing signs and symptoms similar to those described for intramedullary tumors In brief impairment of the spinothalamic tracts produces loss of pain and temperature sense Involvement of the posterior columns is characterized by disturbance of the position and vibratory sense Pyramidal tract involvement is associated with muscle weakness paresis hyperactive tendon reflexes and abnormal extensor plantar phenomena A Brown-Séquard syndrome may result from a tumor which makes lateral pressure on the spinal cord

Other aids helpful in establishing a diagnosis of a neoplasm in the cervical spinal cord or nerve roots are

1 Radiographic study is made on stereoscopic, anteroposterior lateral and oblique views of the cervicothoracic spine Destruction of the pedicles or of the vertebral body may be demonstrable particularly in the presence of an extramedullary tumor Widening of the interpedicular space with or without bone destruction is a significant finding indicative of a neoplasm in the involved area

2 Examination of the cerebrospinal fluid usually reveals an elevated protein level. The fluid is often yellow in color (xanthochromia)

3 Manometric study gives valuable information to determine the presence of a partial or complete spinal subarachnoid block The Queckenstedt test and the method of Grant and Cone (who employ a blood pressure cuff around the neck to obtain varying degrees of compression of the jugular vein) are the most valuable manometric tests

4 Myelography may localize the lesion as well as establish the diagnosis

Syringomyelia

This lesion may produce signs and symptoms similar to those of intramedullary tumors of the cervical spinal cord and occasionally mimics those produced by cervical rib Although pain is not a cardinal symptom of this disease occasional deep boring or burning pain in the shoulder and arm and stiffness of the neck may be prominent features of the clinical picture

This process usually involves the lower cervical and upper thoracic spinal cord Briefly the process comprises proliferation of the glial cells in the region of the central canal (designated central gliosis) cystic degeneration and cavitation of the cord. The process is limited at first to the gray matter of the cord later it involves the white matter It tends to extend upward and downward anteriorly and posteriorly only rarely does it extend laterally across the cord It becomes apparent that the signs and symptoms manifested are dependent upon the area of the cord affected. In the early stages it progresses with relative rapidity however quiescent periods are characteristic of the disease. Other frequent developmental defects are platybasia Klippel Feil deformity and the cervical rib

Syringomyelia is encountered most frequently in the second and the third decenniums, usually it progresses slowly and remains in a quiescent state for many years becoming progressive again Hemorrhage into the cystic tissue may reactivate the process

In the early stages when the process is confined to the gray matter about the central canal loss of pain and temperature sense are the most significant symptoms, and it involves only the spinothalamic tract on one side Inasmuch as the lower cervical and the upper thoracic segments of the spinal cord are the regions most commonly affected the symptoms are projected to the neck the shoulder, the arms and the upper thoracic regions It is common knowledge that syringomyelic patients unknowingly sustain burns of the fingers from lighted cigarettes or hot water This may be the first clue of loss of pain and temperature sense The first indication of the disorder may be numbness of the fingers Loss of pain and temperature is always segmental in nature and found on both sides of the body below the level of the lesion

It is characteristic of this disease that touch deep pressure and position senses are not impaired because the posterior columns are seldom involved Occasionally the posterior columns do become affected and ataxia develops. The cells of the anterior horn are involved with extension of the pathologic process resulting in atrophy weakness and paralysis of muscles Motor disturbances also disclose a segmental arrangement Weakness of the muscles supplied by the ulnar nerve and atrophy of the hypothenar eminence are usually the first motor manifestations Similar involvement of the muscles of the shoulder and the pectoral regions occurs with further extension of the process in the spinal cord Motor manifestations are at first unilateral later both extremities are affected as the process extends to the opposite side of the cord Occasionally the lesion destroys the pyramidal tracts resulting in paralysis or weakness of muscle spasticity hyperactive tendon reflexes and extensor plantar phenomena

Implication of the cells of origin of the sympathetic fibers situated in the lateral horns of the gray matter is exhibited by vasomotor disorders in the upper extremity The hands are moist cool and slightly edematous Sometimes Horner's syndrome is present resulting from involvement of the eighth cervical and the first thoracic segment Trophic changes such as indolent ulcers of the fingers are frequently encountered following burns Rarely neurotrophic joints (Charcot joints) develop in syringomyelia. The shoulder and elbow joints are most commonly affected

Hypertrophic Cervical Pachymeningitis

This lesion is essentially a chronic inflammatory process, involving the dura mater of the cervical segment of the spinal cord and the cervical nerve roots Many cases are syphilitic but most are nonspecific in origin The lesion is not common and may be confused with syringomyelia or intramedullary tumors in the cervical region of the spinal cord Pain in the neck the shoulders and the arms is a prominent factor of the disease The pain may be severe is segmental in nature and is accentuated by movements of the cervical spine This is followed by progressive muscular weakness atrophy and fibrillation of muscles innervated by the affected cervical nerve roots The muscles of the hands and the arms are most markedly affected Extension of the inflammatory process may involve the spinal cord or produce compression of the cord resulting in weakness spasticity and sensory disturbances in the lower extremity Varying degrees of manometric block may exist depending upon the extent of the inflammatory process and the amount of compression of the spinal cord Lesions of syphilitic origin will exhibit positive serology of the blood and the spinal fluid and the diagnosis may be substantiated further by the pres

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joint caused by pain or muscular involvement results in a frozen shoulder which in itself is a markedly disabling malady

Inflammatory Lesions

Epidural abscess may be responsible for segmental pain in the shoulder and the arm It may be a metastatic lesion from a pyogenic focus outside of the central nervous system or it may be a secondary lesion derived from pyogenic organisms in the blood stream The signs and symptoms depend upon the number of cervical and upper thoracic nerve roots implicated and the degree of pressure made by the extradual inflammatory mass on the spinal cord In general, radicular pain is present, also, abnormal sensory and motor manifestations below the level of the lesion Dysfunction of the spinal cord, such as progressive paraplegia, may progress rapidly due to extension of the inflammatory mass which compresses the cord The appearance of flaccid paralysis is an ominous sign

As a rule, diagnosis is facilitated by such associated systemic reactions as spiking temperature range chills prostration, high leukocytosis and low red blood-cell count A frank suppurative area elsewhere may be a diagnostic clue Studies of the cerebrospinal fluid disclose a high cell count and an increased protein level Lumbar puncture usually reveals a complete manometric block of the subarachnoid space

Guillain Barré Syndrome

Pain in the upper extremity and the shoulder may be produced by acute inflammatory processes which involve the peripheral nerves the roots or the cord singly or in combinations often grouped under the all inclusive heading myelo-radiculo-neuritides or the 'Guillain Barré Syndrome.' The syndrome is usually associated with some other systemic infection particularly of the upper respiratory tract. The clinical course is variable Generally there is root pain and varying degrees of motor and sensory impairment. The disease progresses to a certain stage, remains static for a period and then recedes slowly This last phase may persist for many months.

Fig 274 Tuberculosis of the cervical spine in a male, 53 years old. The cardinal symptom was pain referred to the right shoulder and arm

Rapidly ascending lesions with involvement of the brain which have terminated fatally have been recorded Frequently cranial nerves are implicated The cardinal motor features are progressive muscular weakness, flaccid paralysis, loss of deep tendon reflexes and tenderness along the course of the peripheral nerves Characteristic of this syndrome is an increase in the protein content without appreciable change in the cells of the spinal fluid The etiologic agent is obscure Most evidence however, points to a neurotropic virus

LESIONS ASSOCIATED WITH PATHOLOGIC DISORDERS OF THE VERTEBRAL COLUMN

Radicular pain to the shoulder and the arm may result from stimulation of the cervical and the upper thoracic nerve roots or involvement of the deep mesodermal tis-

ence of other signs of syphilis of the central nervous system. However, nonspecific lesions will have a negative blood and spinal fluid serology Excision of the posterior dural covering of the cervical spinal cord followed by irradiation, has been followed by marked relief of symptoms in some instances.

Platybasia (Basilar Compression)

Platybasia is a skeletal deformity characterized by malformation of the occipital bone and the upper cervical vertebrae The foramen magnum is misshapen and narrow the atlas, as a rule is fused with the occipital bone the clivus is displaced upward and the odontoid process compresses the medulla and the cervical segments of the spinal cord Other associated anomalies are *syringomyelia of the cervical segment of* the spinal cord and the Klippel Feil deformity

Gustafson and Oldberg are of the opinion that platybasia is responsible for the formation of cystic defects in the spinal cord similar to that of syringomyelia. List points out that neurologic manifestations associated with this skeletal deformity may result from mechanical compression of the brain stem or developmental defects of the central nervous system Many etiologic factors responsible for platybasia have been cited including osteomalacia rickets and osteitis deformans However, most investigators believe that the lesion is a developmental defect Trauma is not considered a primary causative factor, although it may influence the course of the disease

The signs and symptoms and the character of the clinical course depend upon the degree of mechanical compression and the response of the arachnoid to irritation both factors are capable of causing a partial or complete block of the subarachnoid space It is apparent that the resultant syndrome is variable and may be confused with syringomyelia intramedullary tumor and progressive spastic paralysis. In most instances roentgenographic examination discloses the true nature of the lesion Relief of symptoms may be attained by decompression of the foramen magnum

Herpes Zoster

Herpes zoster is one of the less common causes of pain in the shoulder and the arm. It is an acute infectious disease whose etiologic agent has been definitely established as a filtrable virus. The seat of involvement is the posterior root ganglia posterior roots and posterior gray horns of the spinal cord In more severe forms, the inflammatory process may extend into the anterior roots and give rise to motor disorders This disease is rarely encountered in the young age groups it occurs most often after the fourth decade of life. Implication of the cervical and the upper *thoracic sensory nerve roots produces* radicular pain in the neck, the shoulder or the arm which is segmental in nature and has a pattern of cutaneous distribution depending upon the specific root or roots involved

This disease is ushered in by hyperalgesia and hypersensitiveness in a specific dermatome the pain may be intense and of a burning character From 3 to 5 days after the onset small discrete vesicles appear in the same segmental area corresponding to the affected root or roots Pain is usually severe throughout the entire acute stage A brown pigmentation of the area remains after the vesicles disappear and may persist for an indefinite period Postherpetic intractable pain may ensue particularly in older individuals and it may persist for many years Such distressing sequela often fails to respond to any form of therapy In most cases section of the affected roots fails to alleviate the pain.

Although rare segmental motor involvement may occur it is a more serious problem in the upper extremity than elsewhere. The principal features are weakness or flaccid paralysis of muscles atrophy and loss of deep reflexes In many cases prolonged loss of motion in the scapulohumeral

joint caused by pain or muscular involvement results in a frozen shoulder which in itself is a markedly disabling malady

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Herpes Zoster

Herpes zoster is one of the less common causes of pain in the shoulder and the arm. It is an acute infectious disease whose etiologic agent has been definitely established as a filtrable virus The seat of involvement is the posterior root ganglia, posterior roots and posterior gray horns of the spinal cord In more severe forms, the inflammatory process may extend into the anterior roots and give rise to motor disorders This disease is rarely encountered in the young age groups, it occurs most often after the fourth decade of life. Implication of the cervical and the upper thoracic sensory nerve roots produces radicular pain in the neck, the shoulder or the arm which is segmental in nature and has a pattern of cutaneous distribution depending upon the specific root or roots involved.

This disease is ushered in by hyperalgesia and hypersensitiveness in a specific dermatome the pain may be intense and of a burning character From 3 to 5 days after the onset small discrete vesicles appear in the same segmental area corresponding to the affected root or roots Pain is usually severe throughout the entire acute stage A brown pigmentation of the area remains after the vesicles disappear and may persist for an indefinite period Postherpetic intractable pain may ensue particularly in older individuals and it may persist for many years Such distressing sequela often fails to respond to any form of therapy In most cases section of the affected roots fails to alleviate the pain.

Although rare segmental motor involvement may occur it is a more serious problem in the upper extremity than elsewhere. The principal features are weakness or flaccid paralysis of muscles atrophy and loss of deep reflexes. In many cases prolonged loss of motion in the scapulohumeral

con triction of the nerve root and radicular pain (Turner and Oppenheimer) Others do not agree believing that narrowing of the intervertebral foramina in the vertical diameter (which occurs with degeneration of the intervertebral disks) does not con strict the exits of the nerves sufficiently to produce compre ion (Semmes and Murphey)

In spite of the controversy, it is a clinical fact that *root pain in one or both upper extremities and other manifestations* of nervous origin, uch as numbne s and tin gling in the fingers, and atrophy and weak ness of the muscles of the hands do exist along with osteo-arthritis of the cervical region of the vertebral column Again it must be pointed out that irritation of uch mesodermal ti ues as periosteum fa ciae and ligament implicated in this chronic inflammatory proce , may give rise to deep segmental pain However it mu t be ad mitted that in many in tances of root pain associated with osteo-arthritis of the cervi cal pine the true etiologic factor is not the arthritis per se but protru ion of the inter vertebral disks This causative agent will be considered subsequently

PRIMARY AND METASTATIC NEOPLASMS

Primary bone neopla ms are rarely en countered in the cervical vertebrae Root pain in the upper limb may result from *encroachment of the nerve roots by neo*plastic tissue or bone destruction may cause impingement of the roots in the bony canal Plasma-cell myeloma must be con sidered in patients over 40 years of age who complain of radicular pain in the shoul *ders and arms* who complain of neck stiff ness and who on radiographic studies disclose punched-out discrete areas of bone destruction in the cervical vertebrae Osteo-lytic metastatic bone lesions may exhibit a similar radiographic picture In the latter group however a primary lesion is usually demonstrable In the former study of the bone marrow obtained by sternal puncture confirms the diagnosis

Meta tatic bone le ions to the cervical spine are not rare Le ions secondary to breast or thyroid cancer may produce ex tensive destruction of the affected vertebrae and compre ion of the cervical roots Pain may be severe and intractable more se ere at night deep and boring in character and it may be relieved only by large doses of opiates In two such ca es a cordotomy in the cervical portion of the cord had to be *performed in order to obtain relief*

TRAUMATIC LESIONS

Injuries to the cervical vertebrae produc ing compression of the cervical roots or the cord or both are relatively common Root pain *in the shoulders and the arms* may be the mo t prominent subjective feature of the clinical picture The syndrome may exist without radiographic evidence of fracture or fracture-dislocation of the cervical spine In these instances there is reason to be lieve that luxation and pontaneous reduc tion of the spine occur at the time of the injury (whiplash mechani m) During luxa tion and reduction partial or complete rup-ture of the posterior interarticular ligaments may occur producing pain which has seg mental di tribution similar to that caused by nerve root pressure or irritation (Davis) In one case pain in the right deltoid region and along the dorsolateral a pect of the arm and the radial border of the forearm was the *most significant symptom* Radiographic in vestigation di closed no evidence of frac ture or dislocation of the cervical vertebrae Routine lateral views revealed a straight cervical pine with complete obliteration of the normal anterior curve Lateral views with the cervical pine flexed (chin-chest position) disclosed luxation of the fourth on the fifth cervical vertebra (Fig 275)

Davis points out that luxation of the cer vical spine is a frequent cause of shoulder and arm pain that straightness in routine lateral views is indicative of some obscure pathologic disorders in the cervical region and that luxations are best treated by a hyperextension collar He records that fail

sues by diseases affecting the cervical and the thoracic regions of the vertebral column The most common are

1 Tuberculosis
2 Rheumatoid arthritis (ankylosing spondylitis)
3 Hypertrophic arthritis
4 Primary and metastatic neoplasms
5 Traumatic lesions (fracture fracture dislocations and subluxations)
6 Protrusion of the intervertebral disks

Tuberculosis

In many cases of tuberculosis of the cervical vertebrae root pains in the neck the shoulder and the arm are outstanding subjective findings In one individual radiating pain in the shoulder and the arm was of such severity that it obscured all objective physical findings for many months Pain in these cases is due both to irritation of the cervical nerve roots and to destruction of the tissues of the vertebral column

Other characteristic features are helpful in establishing the diagnosis Stiffness and spasm of the posterior muscles of the neck are invariably present With destruction of the vertebral bodies a kyphosis or gibbus appears in the cervical region All movements of the neck are guarded carefully Roentgenographic study confirms the diagnosis by revealing destruction and collapse of the vertebral bodies forming a frank kyphotic deformity or in earlier cases narrowing of the intervertebral disk associated with some destruction of the bodies with minimal or no spinal deformity Advanced demineralization of the affected and adjacent vertebral bodies and the presence of a soft tissue mass in the region of the osseous involvement are other radiographic characteristics of tuberculosis (Fig 274)

Alterations in the configuration of the spinal canal and distortion of the vertebral column resulting from destruction of the osseous and ligamentous structure progress slowly The spinal cord readily adjusts itself even to extreme deformities of the column Manifestations pointing to compression of the cord usually develop gradually and are produced by extension of the inflammatory process into the epidural space and compression of the cord by the expanding granulomatous tissue

Early signs of cord compression are spasticity increased deep tendon reflexes loss of abdominal reflexes and extensor plantar phenomena, all indicating that the lateral tracts are implicated first Abnormal sensory reactions develop later below the level of the lesion Rarely, sudden collapse of the vertebral bodies may occur, producing acute compression of the cord manifested by a flaccid paralysis Cervical nerve roots may also be compressed by the tuberculomatous mass giving rise to segmental pain. More than one root is usually involved, confusing the segmental pattern of distribution. The cervical segments of the spinal column is less frequently involved than the dorsal and the lumbar regions

Rheumatoid Arthritis

Segmental root pain in the neck and the upper limb is commonly found in the early stages of ankylosing spondylitis involving the cervical vertebrae. In these instances, pain is the result of constriction and irritation of the nerve roots by the inflammatory process implicating the tissues which form the intervertebral foramina. It is doubtful whether any actual bony impingement of the nerve roots exists in these instances. Pain disappears when the acute inflammatory process subsides and bony ankylosis of the vertebral column ensues.

Hypertrophic Arthritis

Varying degrees of segmental pain intensity are frequently a concomitant clinical feature of hypertrophic arthritis in the cervical spine Many workers are of the opinion that osteo-arthritis of this region results from thinning of the intervertebral disks and plays no part in the production of the syndrome They believe that thinning of the disks is responsible for narrowing of the intervertebral foramina thereby causing

ure to treat adequately the early cases results in creeping migration of one vertebral body on the one below which is responsible for segmental pain in the upper extremity. Old lesions may also be treated by a hyperextension collar. If the syndrome recurs Davis recommends spinal fusion. Luxations may be complicated by protrusion of an intervertebral disk which causes pain by direct irritation of the corresponding cervical nerve root.

PROTRUSION OF THE INTERVERTEBRAL DISK

Since the report of Semmes and Murphey, in 1943, emphasized the frequency of extrusion of the intervertebral disks in the cervical region as causative agents for segmental pain in the shoulder and the arm and for sensory disturbances in the finger, it has become apparent that many of these cases had paraded hitherto under such erroneous diagnoses as brachial neuritis, cervical rib or scalenus anticus syndrome and arthritis of the cervical spine.

Although this is true, many other factors may produce a similar clinical picture. For example, the numerous anatomic aberrations of the thoracic operculum may be the basis for mechanical brachial neuritis. When the etiologic agent is uncertain, it becomes apparent that segmental pain in the upper extremity demands careful scrutiny and study before a diagnosis is established. Failure to appreciate the significance of this statement will result in mismanagement of these cases. It is common knowledge that many individuals are victims of needless surgery because of failure to search for and evaluate properly all the numerous possibilities that may be responsible for this distressing symptom complex.

Increasing knowledge of this entity stresses that the symptomatology is variable depending upon the location and the size of the lesion. Prior to the study of Semmes and Murphey (1943) only large protrusions of the disks were recognized. These produced unilateral or bilateral pressure on the cord and simulated extramedullary neoplasms or other neurologic diseases. Small lateral herniations of the disks causing root pain were considered to be extremely rare.

Clinical investigation has reversed this view. Small lateral extrusions of the disks are now considered to be relatively common and are the causative factor in the greater majority of patients exhibiting this syndrome. On the other hand large central herniations of the disks causing compression of the cord are rarely encountered.

Lateral protrusions are observed more frequently in men than in women and they occur more frequently on the left than on the right side. The cervical nerve roots which are implicated most frequently are, in order of frequency, the seventh, the sixth and the eighth.

There appears to be no correlation between severe trauma to the cervical spine and the radicular syndrome of herniation of intervertebral disks. More often the syndrome is initiated by such minor injuries as sudden, unguarded movements of the head. In some instances recurrent episodes of stiff neck or cricks in the neck antedate the onset of the complaints by many months or even years. As pointed out by Semmes and Murphey, stiffness and cricks in the neck may not be the result of fibrosities or some focus of infection, but the result of stretching and tearing the annulus fibrosis of a degenerating cervical disk which are percussors of disk extrusion.

The onset of the disease is generally initiated by a feeling of soreness and stiffness in the neck, then pain of varying intensity radiating to the shoulder, the upper arm, the forearm, and occasionally to the hands and the fingers, becomes the dominant symptom. Paresthesias and sensations of numbness are the outstanding symptoms observed in the hand and the fingers. Rarely there may be paresthesias without pain or pain without paresthesias. The pain usually is sharp and lancinating and follows a segmental pattern. It is accentuated or reproduced by certain movements of the neck and by acts which increase intra abdominal and intrathoracic pressure (Eaton).

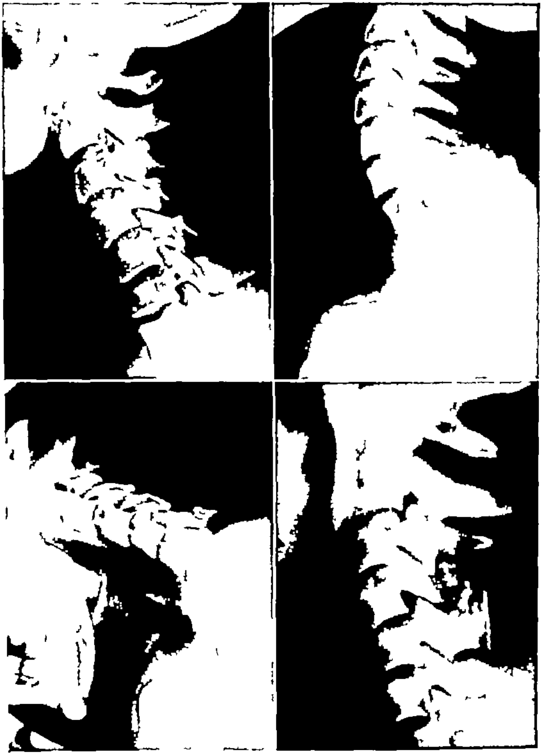

FIG 275 (*Top left*) Lateral view of cervical spine of male, 21 years old 8 weeks following trauma to the cervical spine (by whip-lash mechanism) Observe that the normal forward cervical curve is straightened particularly in the segment formed by the fourth, fifth and sixth cervical vertebrae. (*Top right*) Lateral view with spine hyperextended (same patient) (*Bottom left*) Lateral view with spine hyperflexed (same patient) Note the forward displacement of the fourth cervical on the fifth cervical vertebra. The outstanding symptom in this case was pain radiating into both shoulder and right arm accentuated by forward bending of the neck. Observe the increased interval between the spinous processes of the fourth and fifth vertebrae. (*Bottom right*) Same patient 7 months after injury Note the alteration of the cervical curve and increased forward displacement of the fourth on the fifth cervical vertebra ("creeping migration") This roentgenogram was taken 8 weeks after a fusion of the fourth and fifth cervical vertebrae had been done Coalescence of the bone chips is discernible. This patient was seen for the first time 8 weeks after the injury (his head was snapped forward when the automobile he was driving was forcibly struck in the rear) No treatment had been rendered during this period. A hyperextension collar was then applied which relieved the symptoms he wore the collar for 12 weeks symptoms returned when the collar was removed A spinal fusion (as shown above) was then performed

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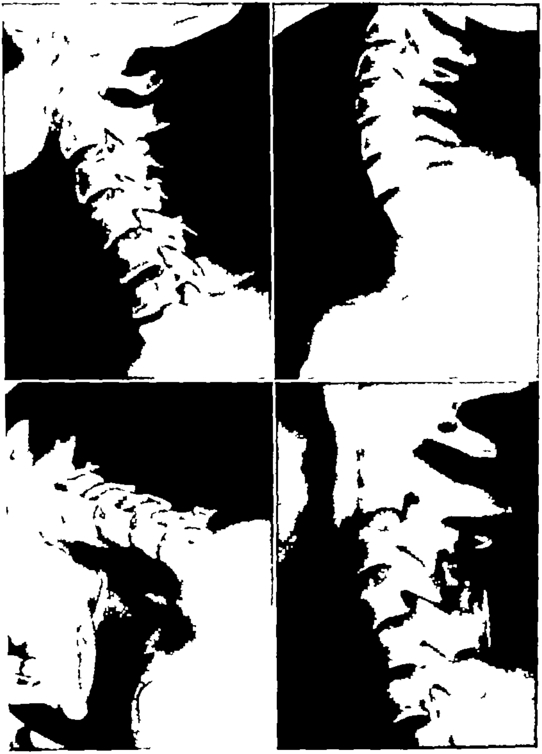

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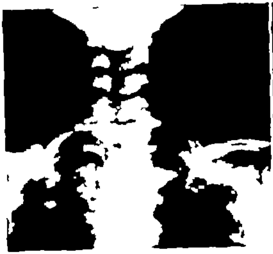

FIG 277 (*Left*) Unusually large transverse processes of the seventh cervical vertebrae
FIG 278 (*Right*) Aberration of the thoracic outlet (bilateral) associated with large cervical ribs and abnormal first thoracic ribs, and an elevated scapula on the left side

Involvement of the anterior root fibers result in varying degrees of atrophy, weakness and fibrillations in the muscles innervated by the affected root Response of deep tendon reflexes of the biceps brachii and the triceps muscles may be altered Diminished or absent tendon reflex of the biceps brachii indicates encroachment of the sixth cervical nerve root Diminished or absent tendon reflex of the triceps points to implication of the seventh cervical nerve root Weakness and atrophy of the muscles of the hand are consistent with involvement of the eighth cervical nerve root and atrophy and weakness of the deltoid with involvement of the sixth nerve root

Many established entities, which may produce radicular pain must be considered in the differential diagnosis Important among these are such aberrations of the thoracic outlet as cervical rib and abnormal first thoracic rib scalenus anticus syndrome neoplasms of the spinal cord and lesions affecting the shoulder region, such as bicipital tenosynovitis calcareous tendinitis, lesions of the musculotendinous cuff and frozen shoulder All these must receive due consideration and they must be excluded by careful physical examination and radiographic studies before diagnosis of protrusion of an intervertebral disk is made.

Valuable information is obtained by adequate radiographic examination The most significant observation is straightness of the spinal column in the cervical region Lateral views may reveal thinning of the involved intervertebral disk and lipping of the anterior and the posterior margins of the adjacent vertebrae (Fig 276)

Myelography, using pantopaque, localizes the lesion in a high percentage of cases and is considered a valuable diagnostic procedure Oblique and stereoscopic views will bring into view the intervertebral foramina and disclose any alteration in their configuration and the presence of bony spurs encroaching on the foramina

Conservative management should be given a trial before surgical intervention is considered Many cases of mild or moderate severity are relieved by restricting movement of the neck by a collar Physiotherapy in the form of radiant heat is a valuable adjunct Traction made with a head halter will relieve many Manipulation is contraindicated at all times

Failure to respond to conservative measures warrants surgical intervention which comprises exploration of the affected nerve root and removal of the extruded disk In cases with large protrusions causing spinal cord compression, surgical intervention certainly should be the primary treatment of choice.

Maneuvers such as the Lasègue maneuver, extreme flexion of the cervical spine and downward traction on the arm which stretches the affected nerve roots also intensify the pain (Eaton)

FIG 276 Lateral view of a female aged 43 Observe the straightness of the cervical spine and thinning of the intervertebral disk between the fifth and sixth cervical vertebrae whose adjacent anterior and posterior margins reveal advanced lipping Conservative measures failed to alleviate the symptoms An extruded disk was found at operation on the left side its removal resulted in disappearance of all symptoms

Pain may be more pronounced during rest when the body assumes a horizontal position This position results in elongation of the spinal column thereby stretching the implicated nerve roots (Eaton) Assuming the upright position alleviates the pain Spurling s "foraminal compression test," in which pressure is applied to the top of the head while the head and the neck are flexed laterally toward the affected side reproduces the radicular pain in most cases especially during the acute phases of the disease Flexion of the neck laterally toward the unaffected side alleviates the pain in some cases but fails in others. Areas of tenderness may be demonstrable in the shoulder, the arm and the wrist. Pressure over the point of exit of the affected nerve root from its intervertebral foramen elicits marked tenderness (Semmes and Murphey)

The segmental pattern of pain and other sensory manifestations will depend upon the specific nerve root implicated, a feature of considerable aid in localizing the lesion Compression of the sixth nerve root produces pain in the shoulder along the dorsolateral aspect of the arm, outer (radial) surface of the forearm, and occasionally in the thumb and the index finger Paresthesias and sensations of numbness are felt chiefly in the thumb and at times in the index finger Implication of the seventh root discloses the same pain distribution as the sixth nerve root However, as recorded by Semmes and Murphey sensory phenomena are concentrated chiefly in the index finger These authors also point out that pain radiating to the precordial region is often a concomitant feature of seventh cervical root involvement and may be confused with angina Compression of the eighth cervical root gives rise to sensory phenomena along the inner (ulnar) aspect of the arm the forearm and the fifth finger often the fourth finger is affected. Pain is also referred to the shoulder region

Motor phenomena are exceedingly variable and depend upon the level the size the location and the duration of the lesion Large extrusions approaching the midline may produce a syndrome similar to an extradural neoplasm compressing the cord and they may cause sensory and motor disturbances below the level of the lesion these are rare lesions More commonly the protrusion occupies a lateral position causing pressure on the dorsal sensory nerve root. Lesions of long duration may also implicate some fibers of the anterior motor nerve root

the *transverse processes* to complete ribs which join with *the first thoracic ribs* anteriorly

Between these two types numerous variations are encountered, some of which join the first thoracic ribs Most often they occur unilaterally but they may occur bilaterally In cases with bilateral ribs one side may vary considerably in length and configuration *from* the other Usually, those with which one is *chiefly concerned* clinically arise *from the seventh cervical* but they may arise from any of the cervical vertebrae At times it may be difficult to distinguish an abnormal first thoracic from a cervical rib Indeed it is doubtful whether cervical ribs per se are responsible for symptoms Evidence seems to indicate that other factors must be associated with this anomaly *before symptoms* arise Chief among these *factors* are

1 Abnormal position of *the shoulder in* relation to the thorax due to congenital or developmental aberrations

2 The presence of a postfixed plexus whose lower fibers must run upward sharply and obliquely to cross the cervical rib in order to reach the lower trunk of the plexus As their course is directed downward into the arm these fibers become acutely angulated *over* the rib *The same abnormal* topographic anatomy *is observed in the absence of a cervical rib and in the presence* of a high first thoracic rib associated with a postfixed plexus

3 Descent of the shoulder resulting from loss of normal muscle tone, occupations which tend to depress the shoulders and trauma

Walshe Jackson and Wyburn Mason postulate that anatomic and developmental factors are responsible for numerous anomalies of the thoracic operculum *which often* result in narrowing of the interval between the clavicle and the upper *thoracic cage* The clavicle in these instances during arm *motion compresses the neurovascular* structures against the abnormal costal elements *In cases* lacking *these* elements, drooping of the shoulder may result in diminution of the costoclavicular space rendering the brachial plexus and the subclavian vessels *vulnerable to compression* by the clavicle Walshe *Jackson and Wyburn Mason also* contend that repeated *minor trauma to* soft tissue maladjusted to the thoracic outlet and clavicle may produce during arm motion secondary inflammatory changes around the nerve trunks and the subclavian vessels, which in turn may give rise to phenomena of compression

Adson expressed the belief that the scalenus anticus muscle was the *prime* etiologic factor of the syndrome regardless of whether a cervical rib was present or not He contends that during the period of greatest muscular development the individual indulges in strenuous physical activities which tend to cause *dropping* of the *shoulders and* that *during this period of life the muscle is more apt to compress the* neurovascular structures than at other periods Naffziger and Grant support Adson's theory and add that removal of a portion of the cervical rib in addition to scalenotomy is sometimes necessary to alleviate the symptoms

Women are affected more *frequently than* men *Despite the fact that in many instances bilateral cervical ribs exist the right side exhibits such* manifestations more often *than the left* The cardinal features of the syndrome are pain in the region of the shoulder, usually radiating to the elbow and the ulnar aspect of the forearm the hand and the fourth and the fifth fingers Parasthesias, such as tingling formication and numbness in the area of pain *distribution* in the forearm and the hand, are concomitant *subjective symptoms Although pain is projected* most often to the region *of the deltoid* muscle, occasionally it is referred to the scapular, the pectoral and the *occipital* regions and along the outer aspect of the forearm In general the sensory phenomena point to involvement of the lower two nerve trunks but at times all three trunks may be implicated

FIG 279 (*Left*) Lateral view of the cervical spine of a case of Kippel Feil deformity There is fusion of the cervical bodies and their posterior elements. (*Right*) Anteroposterior view of a case of Kippel Feil deformity Observe the pronounced asymmetry of the thoracic outlet and irregular formation of the lower cervical and upper thoracic vertebrae On the right there is also a Sprengel's scapula.

LESIONS SITUATED OUTSIDE THE VERTEBRAL COLUMN

Numerous mechanical factors in the supraclavicular region are capable of producing compression of the brachial plexus Lack of knowledge and failure to comprehend the mechanism of these variable factors is often responsible for erroneous diagnoses From a clinical viewpoint these entities are apt to produce similar signs and symptoms especially in the early stages of the disease Thus it becomes apparent that careful clinical analysis is essential and all helpful diagnostic aids should be utilized to establish a correct diagnosis and institute proper treatment

The more common lesions producing syndromes of mechanical compression of the brachial plexus are

1 Hypertrophied or spastic scalenus anticus muscle

2 Anomalies of the scalene muscles

3 Anomalies of the thoracic outlet such as cervical rib abnormal first thoracic rib cervicodorsal scoliosis and Keippel Feil deformity

4 Aberrations of the brachial plexus

5 Compression of the subclavian vessels and the brachial plexus between the clavicle and the first thoracic rib

6 Compression of the subclavian vessels and the brachial plexus by hyperabduction of the arm (subcoracoid pectoralis minor syndrome)

Cervical Rib Syndrome

Numerous anomalies, both of the costal elements and the brachial plexus, occur in the cervicothoracic region Generally, they occur in combination. Aberrations of the thoracic outlet are commonly associated with anomalies of the brachial plexus For example a rudimentary first thoracic rib and a postfixed plexus always seem to be associated The presence of a cervical rib does not produce symptoms of compression of the brachial plexus and the subclavian vessels in all instances. In fact as will be seen the syndrome may exist without cervical anomalies or first thoracic rib

Cervical ribs are uncommon Eaton records that a survey of 7 706 roentgenograms of the thorax disclosed 45 cases of one or more cervical ribs 29 of which were in women Roughly 50 per cent of the cases with cervical ribs exhibit manifestations of nervous or vascular compression. Aberrant cervical ribs exhibit considerable variation in length shape and direction They may form small processes projecting just beyond

the transverse processes to complete ribs which join with the first thoracic ribs anteriorly

Between these two types numerous variations are encountered some of which join the first thoracic ribs Most often they occur unilaterally, but they may occur bilaterally In cases with bilateral ribs one side may vary considerably in length and configuration from the other Usually those with which one is chiefly concerned clinically arise from the seventh cervical but they may arise from any of the cervical vertebrae At times it may be difficult to distinguish an abnormal first thoracic from a cervical rib Indeed it is doubtful whether cervical ribs per se are responsible for symptoms Evidence seems to indicate that other factors must be associated with this anomaly before symptoms arise Chief among these factors are

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3 Descent of the shoulder resulting from loss of normal muscle tone occupations which tend to depress the shoulders and trauma

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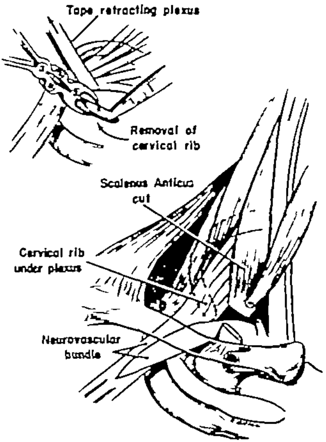

FIG 280. Operative procedure for relief of scalenus anticus syndrome with cervical rib (*Bottom*) Anatomic relationship of the structures producing the syndrome division of scalenus anticus may not suffice to relieve tension of the nerve trunks and constriction of the subclavian artery (*Top*) Resection of a portion or all of the rib may be necessary

The character of the pain is variable It may be deep boring and continuous or sharp and lancinating It may be reproduced or accentuated by acts which depress the shoulder or may be relieved by elevating the shoulder Many of these patients sleep with the arm above the head Tilting the head laterally toward the affected side also relieves the pain, since this position takes all tension off the scalene muscles and the brachial plexus In the light of the work of Wright who showed conclusively that of 150 normal individuals he was able to obliterate the radial pulse in 125 on the right side and on the left side in 124 by hyperabduction of the arm, it is difficult to explain why elevation of the arm relieves pain.

Such abnormal motor phenomena as muscular atrophy, weakness and fasciculations manifest themselves in the later stages of the disease. These changes in the interossei, the hypothenar muscles and the adductor of the thumb point to implication of the ulnar nerve changes in the hyperthenar muscles (abductor pollicus brevis and apponens pollicis) suggest implication of the median nerve (Wilson) Motor manifestations involving the ulnar nerve are encountered more frequently particularly in the presence of a cervical rib

Vascular phenomena are observed sometimes in addition to manifestations of nervous origin. These consist of swelling, coldness tingling and cynosis of the hand and the fingers. Cases are on record of gangrene of the tips of the fingers. In extreme cases the vascular symptoms may be confused with Raynaud s disease or thrombo-angiitis obliterans

Considerable controversy exists as to the factors responsible for vascular phenomena. Some authorities believe that they are the result of varying degrees of occlusion of the subclavian vessels. An arterial bruit resulting from compression of the subclavian artery and with or without a thrill may be heard in the supraclavicular region Walsbe Jackson and Wyburn emphasize that vascular symptoms and signs are caused by compression of the subclavian artery against the costal elements by the clavicle. They describe three syndromes of vascular origin

1 The relatively common syndrome of recurrent coldness cynosis pallor and tingling of the hand and the digits associated with transient obliteration of an otherwise normal radial pulse by placing the arm in certain positions.

2 The syndrome of patent aneurysmal dilatation of the third part of the subclavian artery This may include the components already named and increased pulsation and bruit in addition, with or without a thrill over the subclavian artery above the clavicle.

3 The syndrome of a completely or partly occluded aneurysmal dilatation of the third

FIG 281 (*Left*) Bilateral cervical ribs in a female aged 22 Pain was projected to the right shoulder elbow, and ulnar surface of the forearm and into the fourth and fifth fingers. Atrophy of the muscles of the hypothenar eminence existed No symptoms were present in the left extremity (*Right*) Anteroposterior view of the patient at left After division of the scalenus anticus muscle it was noted that the nerve trunks were tightly stretched over the anterior portion of the rib This segment of the rib was resected

part of the subclavian artery, consisting of signs of ischemia in the limb and sometimes of embolism in the digits leading to small regions of gangrene.[1]

Other investigators support the hypothesis that vascular symptoms follow pressure on the sympathetic fibers in the first thoracic nerve root at the point where it is angulated and stretched over the rib (Stopford and Telford Wilson) Cases of Horner's syndrome associated with cervical rib syndrome have been reported In some instances it is evidence that the sympathetic trunks are implicated although it must be admitted that the seat of involvement may be in the stellate ganglion

SCALENUS ANTICUS SYNDROME

It is general knowledge that the symptom complex just described is encountered also in patients with no cervical ribs. In fact a cervical rib is demonstrable radiographically in the minority of the patients who exhibit the syndrome Since the report of Adson and Coffey (1927) (in which is described relief of nervous and vascular pressure symptoms by division of the scalenus anticus muscle alone in cases with and without cervical ribs) the role of this muscle has assumed considerable prominence Ochsner Gage and DeBakey (1935) observed at operation that the scalenus muscle which is innervated by fibers from the brachial plexuses, was hypertrophied and spastic they attributed its hypertonicity and increased size to irritation of the brachial plexus by a normal first thoracic rib The observers contend that a low shoulder girdle high sternum high first thoracic rib or a postfixed brachial plexus alone or in combination may be responsible for irritation of the plexus by a normal first rib Irritation of the plexus in turn causes spasm and hypertrophy of the scalenus muscle The spastic muscle forces the first rib upward causing further irritation of the brachial plexus, thereby establishing a vicious cycle

It is apparent that any condition capable of causing sagging of the shoulders may institute the syndrome Such conditions are muscular atonia observed in debilitating

[1] Walshe, F M R., Jackson H Wyburn, M R. On some pressure effects associated with cervical and rudimentary "normal" first ribs, Brain 67 164 1944

diseases nervous disorders, occupations which tend to depress the shoulders, trauma, producing a forceful downward thrust on the shoulders and fatigue This is especially true if the afore-mentioned anatomic and developmental abnormalities exist Stopford and Telford emphasize that the combination of a postfixed brachial plexus and a low shoulder girdle observed in adults in whom the lower components of the brachial plexus are stretched tightly over the normal first rib renders the individuals vulnerable to the disorder Factors which induce further descent of the shoulder, as previously noted, are apt to produce symptoms of compression

Many investigators will not recognize the scalenus syndrome as a distinct entity others maintain that the scalenus anticus muscle is only rarely the prime operative cause of irritations of the plexus Nevertheless numerous workers report brilliant results attained by scalenotomy alone in cases with or without cervical ribs Critical analyses of many cases in which this procedure was carried out reveal that the results have

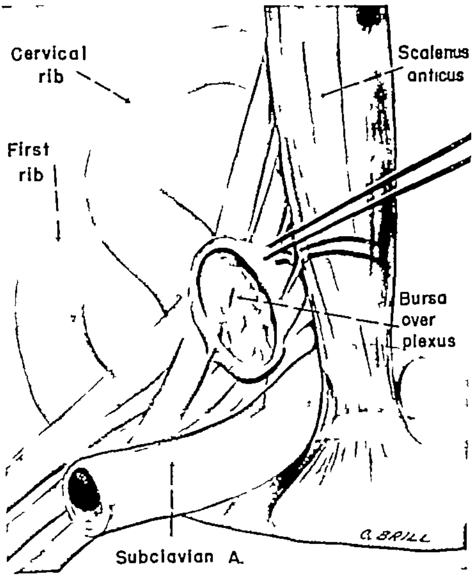

FIG 282 Drawing of an anatomic specimen showing compression of the subclavian artery and brachial plexus between the scalenus anticus muscle and a well formed cervical rib A bursa with thickened walls had formed immediately above the nerve trunks. In the drawing, the top of the bursa has been removed to show the floor of the structure resting on the brachial plexus.

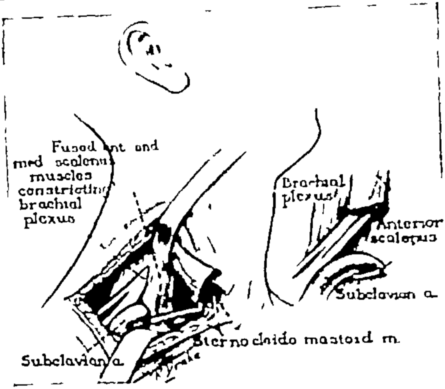

FIG 283 Brachial plexus is constricted by an anomalous formation of the scalenus anticus and scalenus medius muscles. (Allen E. V, Barker, H W, and Hines, E H Jr Peripheral Vascular Diseases Philadelphia Saunders, p 306)

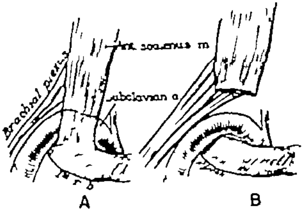

FIG 284 Relationship of structures without a cervical rib the scalenus muscle may be hypertrophied constricting the neurovascular structures against the first thoracic rib (Craig W McK and Knepper P A Cervical rib and the scalenus anticus syndrome Ann Surg 105 556-563)

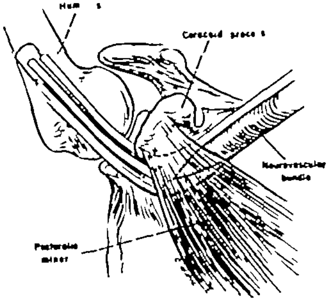

FIG 285 Drawing from anatomic specimen showing mechanism of subcoracoid pectoralis minor syndrome With the arm hyperabducted the neurovascular structures are pulled tightly around and beneath the coracoid process and compressed by the pectoralis minor

been good in some and poor in others, leading one to conclude that the scalenus muscle may be the prime operative factor in some instances in others contraction and spasm of the muscle may be secondary to some other primary lesion

A scalenus anticus syndrome may be associated with extrusions of intervertebral disks of the cervical spine injuries to the vertebrae and ligamentous tissues in the cervical region, compression mechanisms rheumatoid and hypertrophic arthritis of the cervical spine and a host of other lesions affecting this region The syndrome may be associated with an anomalous relationship between the plexus and the scalene muscles

diseases, nervous disorders occupations which tend to depress the shoulders, trauma, producing a forceful downward thrust on the shoulders and fatigue This is especially true if the afore-mentioned anatomic and developmental abnormalities exist Stopford and Telford emphasize that the combination of a postfixed brachial plexus and a low shoulder girdle, observed in adults in whom the lower components of the brachial plexus are stretched tightly over the normal first rib, renders the individuals vulnerable to the disorder Factors which induce further descent of the shoulder, as previously noted, are apt to produce symptoms of compression

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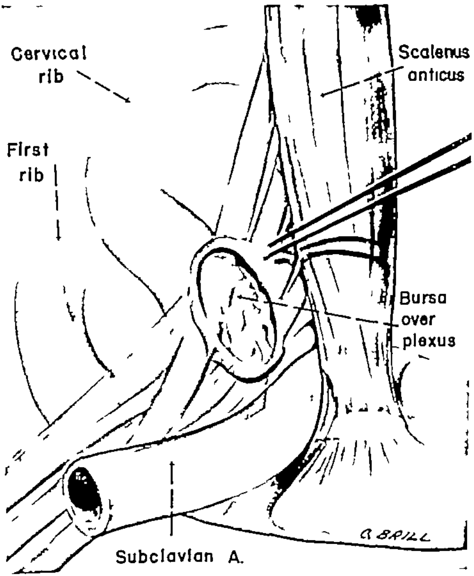

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fibers (Fig 283) The brachial plexus and the subclavian artery may be compressed between the distal ends of the scalenus anticus and the scalenus medius muscles close to their insertions into the first rib (Fig 284)

Symptoms and signs of the scalenus syndrome are similar to those of cervical rib syndrome Horner's syndrome has been observed in some cases of both syndromes Palpation of the supraclavicular fossa will reveal a firm bony prominence if a cervical rib exists. Pressure over the scalenus anticus muscle elicits extreme local tenderness and aggravation of the pain along the ulnar aspect of the arm and the forearm This is true whether or not a cervical rib is present Often, on palpation, the scalenus anticus muscle on the affected side feels tense firmer and hypertrophied, as compared with the opposite side Changes in the character of the pulse and blood pressure during various maneuvers are no longer of any significant clinical value, because as will be shown subsequently, *they occur in normal* individuals and they are produced by other mechanisms which compress the subclavian vessels. Roentgenographic studies are essential for determining the configuration of the thoracic outlet as well as the presence of cervical or abnormal first thoracic ribs

Subcoracoid Pectoralis Minor Syndrome and Costoclavicular Syndrome

Wright demonstrated that compression of the brachial plexus and the subclavian vessels occurred when the arms of normal subjects were hyperabducted This maneuver produced a neurovascular syndrome which resembled closely cervical rib and scalenus anticus syndrome Hyperabduction of the right arm above the head resulted in obliteration of the pulse in *125 of 150* normal individuals the same maneuver on the left side produced obliteration of the pulse in 124 of 150 normal individuals The level of abduction just below the level which would produce obliteration of the pulse was designated the "marginal position"

Three individuals with the arm in the marginal position could obliterate the pulse by deep respiration while in two others the pulse became more prominent Eight subjects *with the arm in the marginal position* could obliterate the pulse by muscular contractions He further noted that turning the head toward or away from the arm tested may open or close the subclavian artery that *flexion of the cervical spine* reduced the incidence of obliteration, and hyperextension increases the incidence

Investigation on anatomic specimens disclosed two mechanisms which caused com*pression of the neurovascular structures in* no way related to a cervical rib or the scalenus anticus muscle

1 By hyperabduction of the arm the brachial plexus and the subclavian vessels *are pulled tightly around and* beneath the coracoid process and at the same time, compressed by the pectoralis minor muscle, the greatest amount of torsion occurring at the point of transition between the sub*clavian and the axillary artery and vein.*

2 Compression of the subclavian vessels and the brachial plexus is effected by reduction of the costoclavicular space

Certain movements of the shoulder girdle such as pulling the shoulders backward and downward and by hyperextension of the neck compress the neurovascular structures between the posterior surface of the clavicle and the anterior surface of the first rib This mechanism was also described by Falconer and Weddell who noted that symptoms of vascular and nervous compression was a common phenomenon They were able to produce it in 25 of 50 normal men and in 30 of 50 normal women These observers explored the supraclavicular region of one patient who manifested symptoms and signs *of a scalenus* anticus syndrome and noted that section of the scalenus anticus muscle did not prevent obliteration of the pulse when the neck was hyperextended and the shoulders were forced downward and backward They *noted at operation* that the aforementioned movements caused diminu

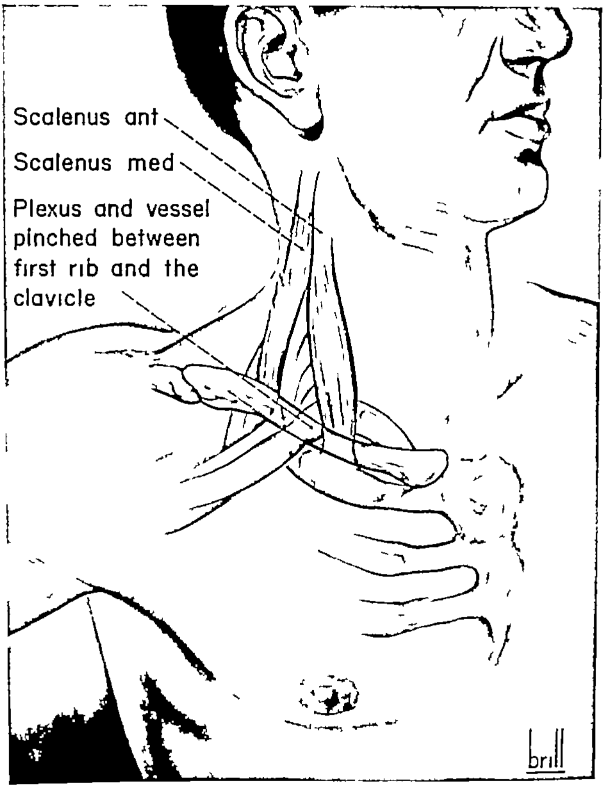

FIG 286 Drawing from anatomic specimen showing mechanism of costoclavicular syndrome. Observe that, with the shoulder drawn downward and backward, the neurovascular structures are compressed between the clavicle and first thoracic rib

Occasionally the bellies of the scalenus medius and the scalenus anticus are fused into one mass, through which traverse the trunks of the brachial plexus again the trunks may split the fibers of the scalenus anticus muscle instead of passing through the interval between the scalenus anticus and the scalenus medius muscles. In both instances the nerve trunks may be readily compressed by the surrounding muscle

of the lung with evidence of erosion of the upper ribs, the transverse processes and in some instances, the vertebral bodies (Fig 287)

Some investigators maintain that the sympathetic manifestations (Horner's syndrome) are the result of pressure on the sympathetic fibers in the common trunk from the eighth cervical and the first thoracic. Others contend that they result from involvement of the stellate ganglion, which lies just anterior to the head and the neck of the first rib, or slightly below this level Sensory and motor manifestations pointing to involvement of the eighth cervical and the first and the second thoracic *nerve roots and Horner's syndrome* are the principal features of this symptom complex.

Neoplasms arising from the sheath cells of the nerves comprising the brachial plexus anywhere along their course may be responsible for pain projected to the shoulder or the arm

Neurinoma commonly arise from the cervical and the thoracic roots of the spinal nerves. They produce segmental sensory and motor phenomena and exhibit such characteristic features of root involvement as exacerbation of pain by increased intra thoracic or intra abdominal pressure and by maneuvers designed to stretch the nerve roots As a rule neurinomas appear as single lesions. However, they may be multiple particularly if associated with generalized neurofibromatosis Single neurofibromas occasionally arise from the nerves of the brachial plexus and may be demonstrable by palpation of the cervical the supra clavicular or the axillary regions The brachial plexus may be implicated in generalized neurofibromatosis

INFLAMMATORY LESIONS

Increasing knowledge of the numerous factors that may account for neck, shoulder and arm pain has reduced considerably the number of heterogeneous entities hitherto grouped under the all inclusive term "brachial plexus neuritis.

FIG 287 Roentgenogram of the thoracic outlet of a case of Pancoast tumor Observe the soft tissue mass in the lower cervical and upper thoracic regions (right side) and erosion of the first and second thoracic ribs and transverse process of the seventh cervical vertebra

Involvement of the brachial plexus may occur in infectious neuritis such as may be associated with infectious diseases like diphtheria scarlet fever typhoid fever or other systemic infections, such as tuberculosis and syphilis However there is no convincing evidence that such foci of infection as may be found in the teeth, the prostate, the gall bladder or the appendix will give rise to pains in the extremities by producing agents (toxins) which act directly on the nerve tissue

Clinical investigation discloses that the greater majority of cases exhibiting this symptom complex fall into one of the three following groups (1) Lesions of the musculotendinous cuff (2) protrusion of inter vertebral disks in the cervical region and (3) bicipital tenosynovitis

Localized *suppurative processes in the* supraclavicular and the axillary regions may implicate the nerve by direct extension

SERUM NEURITIS

Varying degrees of sensory and motor *disturbances occasionally* arise following injection of sera Signs and symptoms of nerve involvement manifest themselves about two days after the onset of serum

tion of the costoclavicular space and compression of the subclavian vessels Resection of portion of the first thoracic rib at the site of maximum compression relieved the patient of all symptoms.

Moreover hyperextension of the neck and backward and downward displacement of the shoulders no longer produced obliteration of the pulse The above observers and Walshe, Jackson and Wyburn Mason called attention to the numerous anatomic and developmental factors which may predispose to compression by the costoclavicular mechanism Notably among these are a high first thoracic rib high fixed sternum abnormal descent or sagging shoulders and abnormal thoracic operculum.

It is obvious that tests (such as hyperextension of the neck turning the head to one side or the other together with deep respiration hyperabduction of the arms and depressing the shoulder girdle) hitherto used for scalenus anticus and cervical rib syndrome are no longer useful diagnostic aids. As has been shown these same tests produce phenomena of obliteration of the subclavian artery in normal individuals Also, it has been pointed out that several mechanisms can produce the same compression phenomena

Treatment

Adequate evaluation of the symptom complex is essential before therapy is instituted Simple scalenotomy may result in a high percentage of failures if done indiscriminately

The presence of a cervical rib associated with well-developed manifestations of nervous compression and vascular destruction is conclusive evidence that the anomalous rib is the prime operative agent Operative intervention is indicated in these instances Division of the scalenus anticus alone may relieve the symptoms however resection of varying portions of the cervical rib may also be necessary In other instances especially in those in which no abnormality of the costal elements or thoracic outlet is demonstrable by roentgenograms, conservative measures should be instituted These comprise elimination of activities which tend to place the arm in hyperabduction, keeping the arms below the horizontal position during sleep, making the patient posture-conscious by insisting that the shoulders be maintained in an elevated position at all times exercises to improve the tone of the muscles of the shoulder girdle, and general measures to improve the economy as a whole

In cases with severe symptoms, failure to respond to a conservative regimen justifies surgical exploration of the supraclavicular area in search of the cause responsible for the compression phenomena Again it must be emphasized that surgical intervention is warranted only after all possible etiologic factors have been duly considered

TUMORS

Primary and secondary metastatic neoplasms may involve the brachial plexus and may produce radicular pain and signs and symptoms of vascular compression in the upper extremity Primary bronchogenic carcinoma of or metastatic lesions to the apices of the lungs may implicate the neurovascular structure in the supraclavicular and the cervical regions by direct extension. Not infrequently carcinoma of the breast even after a radial mastectomy will invade the brachial plexus. Lymphosarcoma and Hodgkin s disease involving the lymph nodes in the supraclavicular and the cervical regions may produce the syndrome

Pancoast in 1924 described an apical lung tumor which he designated superior pulmonary sulcus tumor The derivation of this tumor is not clear Pancoast expressed the belief that it was of epithelial origin. Its characteristic features are pain referred to the shoulder region the axilla and down the ulnar aspect of the arm atrophy and weakness of the muscles of the hand chiefly the interossei and the hypothenar muscles Horner s syndrome and roentgenographic evidence of a pulmonary mass in the apex

of the lung, with evidence of erosion of the upper ribs, the transverse processes and in some instances the vertebral bodies (Fig 287)

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sickness Although other peripheral nerves may be affected, there appears to be a predilection for the upper components of the brachial plexus The injection site is in no way related to the specific nerves implicated Cases of serum neuritis of the brachial plexus have been reported following injection into the abdominal wall Implication of the axillary nerve is a common sequel

Evidence of the neuritis is first noted by intense pain in the shoulder region and along the outer aspect of the arm Sensory and motor phenomena appear following a definite segmental pattern pointing to involvement of specific cervical nerve roots usually the fifth and the sixth Muscular weakness atrophy decreased muscle reflexes and paralysis are the outstanding motor signs The muscles most commonly affected are the deltoid the biceps the brachialis and the brachioradialis all innervated by the upper elements of the brachial plexus Recovery is the rule the period for complete recovery depending upon the regeneration time required by the affected nerve The pathologic disorder responsible for the neuritis is believed to be a localized inflammatory process involving the perineurium which compresses the nerve fibers

TRAUMATIC LESIONS

Trauma to the brachial plexus and its peripheral nerves accounts for pain and disability of the upper extremity in a large number of cases According to Grinker and Bucy 10 per cent of all traumatic cases in civil life are due to birth injuries and 12 per cent to the automobile Injuries which depress the shoulder or increase the angle between the shoulder and the neck are responsible for many brachial lesions (partial or complete) Direct pressure into the axilla (crutch paralysis) is another form of injury Too often the position of the upper extremities of patients on the operating table is responsible for nerve lesions due to prolonged traction and torsion of the plexus Penetrating and lacerating wounds in the supraclavicular, the infraclavicular and the axillary regions are apt to produce bizarre syndromes This has been amply demonstrated by war injuries to these regions

Other types of minor traumata may also be operative factors in producing brachial plexus lesions Chief among these are repeated traumata to nerves, sustained during the performance of certain occupations. Fracture dislocations and dislocations of the shoulder joint are complicated not infrequently by injuries to the brachial plexus or its branches

OBSTETRIC PARALYSIS

Introduction

Three types of obstetric paralysis are recognized clinically (1) the upper-arm or Erb-Duchenne type (2) the lower-arm or Klumpke type and (3) the whole-arm type.

Immediately after birth the extremity usually exhibits the clinical features of flaccid paralysis implicating the entire limb The arm assumes a characteristic position it is kept extended at the side of the body the upper arm rotates internally the forearm is pronated forcing the palm to be directed backward and outward and the wrist may be flexed slightly In mild forms there may be some voluntary motion in the fingers the hand the wrist and the elbow No motor power is noted in any part of the limb in the more severe cases Fortunately evidence of return of motor power is manifested in most cases within a relatively short period of time Voluntary motion starts first in the fingers then in the hand the wrist and the elbow Spontaneous recovery continues until the level of permanent nerve injury is reached where no recovery is possible The group of muscles paralyzed corresponds to the roots implicated Many cases of palsy are associated with injuries to the osseous components of the joint which may not be evident at birth but may be demonstrable radiographically as early as 3 weeks later Fractures near or through the epiphyseal plate may

occur, the proximal humeral epiphysis may be traumatized or displaced for varying distances on the metaphysis. Posterior subluxation of the epiphysis is commonly encountered in the more severe types Such injuries favor maldevelopment of the epiphysis and of the glenoid cavity and they cause marked impairment of function, even in the presence of good motor power

Etiology and Pathogenesis

There is general agreement that trauma inflicted on the child during its exit from the birth canal plays a major role in the production of these palsies. The belief is substantiated by the following clinical facts

1 Lesions are associated most frequently with prolonged and difficult labor

2 A large proportion of the children affected are delivered by forceps

3 First borns are affected more frequently

4 Breech presentations show a higher percentage of paralytic conditions than vertex presentations.

On the other hand there are many divergent concepts as to the pathogenesis of obstetric paralysis Many observers postulate that there is direct injury to the component parts of the brachial plexus The nerve trunks are overstretched by forceful separation of the head and the shoulders. This results in injury to the nerves in continuity (nerve fibers are frayed within the sheath) or by rupture of the roots. Rupture may occur anywhere along the trunks or the roots may be avulsed from the spinal cord The number of roots affected and the severity of the lesions vary considerably generally the upper roots are implicated first and sustain more severe injury than the lower roots In addition to the intrinsic nerve injuries usually there are varying degrees of soft tissue damage such as tearing of the deep cervical fascia and the nerve sheaths rupture of blood vessels and hemorrhage and exudation from traumatized structures In the subsequent healing process the nerves may be entangled in a mass of contracting scar tissue this offers a formidable barrier to nerve regeneration Supporters of this premise believe that shoulder deformities particularly subluxation of the head of the humerus, are secondary manifestations due to contracture of unopposed muscles

Taylor was unable to demonstrate a posterior dislocation in children under 3 weeks old although this deformity progressive in nature was discernible in children after 3 weeks In a number of additional cases operated upon, Taylor and others noted complete rupture of the upper roots of the brachial plexus and in some actual avulsion of the roots from spinal cord

T T Thomas was in total disagreement with the above mentioned theory He was of the opinion that the prime etiologic factor is injury to the shoulder joint structures particularly the capsule and posterior subluxation of the humeral head at the time of birth He believed that extravasation of blood and tissue fluids into the axilla set up an inflammatory process which subsequently involved the brachial plexus and produced paralysis, followed by fibrous tissue formation which in due time is absorbed so that paralysis gradually disappears He believed also that at the time of injury the acromion process is bent downward in front of the humeral head preventing spontaneous repositioning of the head in the glenoid cavity and maintaining it in a fixed subluxated position

He maintained moreover that very rarely was actual nerve rupture a concomitant lesion of the paralysis In support of this concept he offered the following pertinent clinical observations

1 There is almost uniform and gradual disappearance of the palsy

2 Dysfunction of the limb in adults is not the result of paralysis but of a posterior dislocation of the shoulder

3 Immediately after birth the paralysis of the limb is extensive and not limited to a specific group of muscles

4 Correction of the deformity of the

shoulder is invariably followed by improvement of function

In the light of the work in support of the two theories discussed above, it is more reasonable to conclude that some cases of obstetric palsy are the result of direct injury to the brachial plexus with subsequent true paralysis of specific groups of muscles others are pseudoparalysis caused by shoulder joint trauma with deformity simulating true paralysis while in still others both concepts may be applicable

Older children invariably reveal clinically and radiographically changes in the bony architecture of the joint Varying degrees of posterior subluxation of the head of the humerus may exist in such cases the acromion is usually elongated and bent forward and downward in front of the humeral head the coracoid process also may be elongated and crooked in front of the head torsion of the humeral shaft is demonstrable after the age of 3 the humeral epiphysis is underdeveloped and malshaped the scapula rides high and is rotated inward and finally the glenoid cavity is flattened.

TREATMENT

Adequate treatment should be instituted immediately after birth The extremity is placed in a position of abduction and external rotation to prevent adduction and flexion deformities of the shoulder and internal rotation of the humerus This is best achieved by a light splint which fixes the arm in the coronal plane 90 abduction and external rotation the forearm is flexed 90 and fully supinated the wrist is dorsiflexed (Fig 288) Remarkable recovery of motor power is discernible in the first 3 months in the great majority of cases Gentle passive stretching of the shoulder in external rotation and abduction with the forearm in supination is a valuable adjunct to the treatment If the child tends to use the unaffected arm more than the affected arm while the brace is off the good extremity should be tied or pinned to the side to promote more use of the impaired limb These measures must be strictly executed

Conservative measures are employed in the upper-arm type to prevent contractures and to re-educate weakened muscles Ex

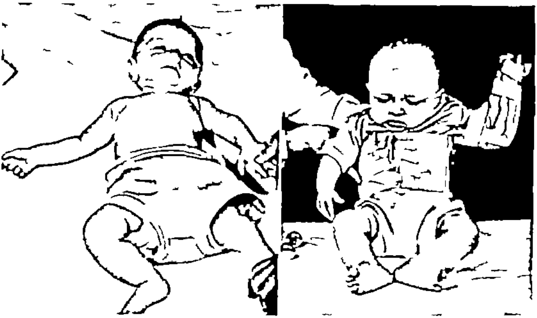

FIG 288 (*Left*) Child with the upper arm form of obstetrical palsy (Erb-Duchenne) The forearm is extended and pronated the upper arm is rotated inward and cannot be abducted. (*Right*) Abduction brace for obstetrical paralysis.

ploration of the brachial plexus seldom has much to offer but may be attempted especially if the paralysis is limited to a specific group of muscles Sever recommended waiting until the fourth or the fifth year before contemplating surgical intervention, at which time severance of contracted soft tissue structures may be done also Although the results are usually disappointing some observers (Taylor for example) recommend exploration of the brachial plexus at the end of three months in cases showing no spontaneous recovery, particularly in the whole arm type

In older children with posterior dislocation of the shoulder the muscle-cutting operation of Sever and elevation or removal of the acromion process improves both the function and the cosmetic appearance of the extremity

Types of Obstetric Paralysis

Upper Arm or Erb-Duchenne Type. This lesion is encountered most frequently of the three types of obstetric palsies The fifth and the sixth cervical roots are involved thereby causing paralysis of the deltoid the biceps the brachialis and the supinator longus muscles Occasionally, the supraspinatus the infraspinatus, the subscapularis and the supinator brevis muscles and the extensors of the wrist and the fingers may be implicated

The condition is produced by spreading the interval between the head and the shoulder (such as occurs when traction is made on the head at birth) or by forcing the shoulder downward and backward The limb assumes a characteristic attitude both the arm and the forearm are adducted and internally rotated the forearm is extended and pronated Lesions of long duration exhibit marked atrophy of the deltoid, the biceps the brachialis and the supinator muscles Motion is greatly impaired There is loss of abduction and external rotation of the arm and loss of flexion and supination of the forearm

A pertinent clinical feature is the lack of sensory disturbances except for a small patch of loss of sensation over the posterolateral aspect of the shoulder This can be explained readily by the extensive overlap of sensory fibers of intact nerve roots Such is not the case in complete lesions implicating the entire plexus, in which there is profound sensory loss—in fact complete anesthesia of the upper extremity Generally, with correct management in obstetric upper arm palsies the prognosis for partial or complete recovery is favorable

Lower Arm or Klumpke Type This lesion is indeed rare It implicates the eighth cervical and first thoracic nerve roots producing paralysis of the muscles which are supplied by the ulnar and inner head of the median nerves The intrinsic muscles of the hand and the flexors of the forearm are involved Cervical sympathetic nerve fibers traversing the lower two nerve roots may be injured producing pupillary inequality (the pupil on the affected side is reduced in size) This is a rare concomitant finding As a rule the prognosis for recovery is poor if such an abnormal sympathetic manifestation persists

The lesion is produced by forcing the extremity upward, hence making tension on the lower roots of the plexus (such as is caused from traction made in breech presentations with the arm extended) Atrophy of the paralyzed muscles and incomplete closing of the hand occurs, and sensory loss is demonstrable in the dermatomes of the eighth cervical and first thoracic nerve roots

Whole Arm Type This lesion is characterized by implication of the entire plexus there is flaccid paralysis of the entire extremity and the wrist paralysis of the small muscles of the hand and complete sensory loss Many gradations in severity occur between the upper arm and the whole arm types depending upon the extent of the injury and the number of roots affected Both extremities may be involved

Operative Procedures for Obstetric Paralysis

Sever's operation is the most popular means of relieving the adduction and internal contractures in cases of obstetric paralysis. Optimum restoration of function depends upon proper selection of cases and adequate physical therapy in muscle development prior to operation

The procedure should not be performed before the age of 4 or 5 years and yields the best results when posterior subluxation or posterior torsion of the head of the humerus are not associated lesions The best functional results are attained in cases which exhibit pronounced dysfunction of the shoulder, cases with slight limitation of motion are not benefited sufficiently to warrant *surgical intervention.*

Sever's Technic. An anterior skin incision is made beginning at the tip of the acromion to below the insertion of the pectoralis major muscle The deltopectoralis *cleft is developed, taking care not to injure* the cephalic vein By retracting the deltoid laterally, the tendinous insertion of the pectoralis major comes into view and is severed close to its insertion

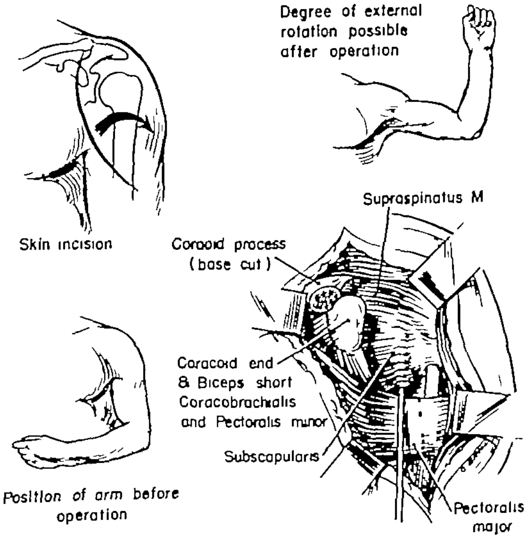

Fig 289 *Sever's operation for obstetrical paralysis.* (*Top left*) Skin incision. (*Top right*) After operation the arm can be adducted readily and rotated externally (*Bottom left*) Before operation the arm is held to the side *adducted* and rotated internally (*Bottom right*) Division of the pectoralis major and the subscapularis tendon. The tip of the coracoid is removed together with the short head of the biceps the coracobrachialis and the pectoralis minor

Medial retraction of the pectoralis major with the extremity abducted and rotated externally uncovers the coracobrachialis muscle, which is traced to its origin from the coracoid process. Generally the tip of the coracoid is found to be elongated and crooked downward in front of the head of the humerus. Its tip (together with the insertion of the coracobrachialis, the short head of the biceps and the pectoralis minor muscles) is osteotomized at its base and removed. Approximately one quarter to three eighths of the tip is removed. With retraction of the coracobrachialis and the short head of the biceps downward and removal of the tip of the coracoid process, considerable gain is achieved in abduction and external rotation.

Next, the tendon of the subscapularis muscle is identified as it inserts into the lesser tuberosity. A curved director is passed beneath the tendon from below upward, and the tendon is divided completely across, without cutting the fibrous capsule. Division of this tendon allows optimum elevation, abduction and external rotation of the humerus.

Complete abduction may be impeded by elongation and hooking of the acromion. Resection of a portion of the end of the acromion will remove the bony block. To obtain complete abduction in old and severe contractures it may be necessary (in rare cases) to divide the insertion of the latissimus dorsi and the teres major muscles through an approach along the posterior axillary fold (Steindler).

Postoperative Management

Following operation, the arm is immobilized in an abduction plaster-of-Paris shoulder spica. It is maintained in abduction and external rotation for from 10 to 14 days. The cast is then removed, and an abduction brace is applied to hold the arm in the above position. Essential features of the postoperative regimen are physical therapy, in the form of massage, stretching, active and passive motion, and particularly muscle re-education.

This procedure gives uniformly satisfactory results in the majority of cases of obstetric paralysis involving the upper arm. The arm is still far from normal, but its function is greatly enhanced.

Osteotomy of the Humerus and Muscle Release

In many children exhibiting adduction and internal rotation contracture of the shoulder, no evidence of muscle paralysis is demonstrable. T. T. Thomas believed that such lesions were primarily those of injury to the shoulder joint at the time of birth, followed by an inflammatory process in the axilla which produced a pseudoparalysis. With healing and absorption of the inflammatory tissue the paralysis disappears. He also believed that posterior subluxation of the head of the humerus and bending of the acromion process occurred at the time of the initial injury. When maintained in a position of posterior subluxation by contracture of the adductors and the internal rotators of the humerus and the bent acromion, the humeral head undergoes varying degrees of posterior torsion, which precludes replacement and maintenance of the head in the glenoid cavity by simple division of the subscapularis and the pectoralis major muscles.

In these cases repositioning and maintenance of the humeral head in the glenoid cavity is achieved best by the addition to the Sever operation of an osteotomy through the surgical neck of the humerus.

Operative Technic (Scaglietti). The first step consists in the correction of the adduction and internal rotation deformity by Sever's operation, as described above. The head of the humerus is thus restored to its normal anatomic relationship in the glenoid fossa. The extremity is then placed and maintained in abduction and external rotation for 8 weeks. Next, through the lower end of the anterior incision, a transverse osteotomy is done through the surgical neck

of the humerus While the upper head portion of the humerus is held in its normal position, the distal portion is rotated internally

Postoperative Management. Immobilization of the extremity in a plaster-of Paris shoulder spica is maintained until bony union occurs Removal of the cast is followed by intensive physical therapy particularly muscle re-education

Osteotomy of the Humerus. *Simple osteotomy* to correct internal rotation deformities through the surgical neck of the *humerus* may be performed in cases exhibiting no posterior torsion or subluxation of the head of the humerus (Vulpius Lange Rogers) Although the cosmetic results are desirable the improvement in function does *not justify* the procedure From a functional viewpoint Sever s operation in these cases is far superior to osteotomy of the humerus

Correction of Internal Rotation Deformity and Posterior Subluxation of Humerus by Reattachment of Capsule and External Rotators (Kleinberg) Kleinberg designed the operation for correction of internal deformities of the humerus associated with posterior torsion and posterior subluxation of the humeral head. Essentially, it consists of a subperiosteal detachment of all the rotators and the capsule from the upper 1 to 1½ inches of the humerus Two flaps are created a *lateral* flap comprising the external rotators and fibrous capsule and a medial flap, consisting of the subscapularis muscle and fibrous capsule Freed of all muscular and capsular attachment, the humerus is readily rotated externally The lateral flap is drawn more medially and is sutured in this position it is overlapped by the medial flap

Correction is achieved and maintained by this procedure However, extensive stripping of all soft tissues from the upper end of the humerus is likely to cause vascular damage resulting in degenerative changes and disturbance in growth of the upper end of the humerus Kendrick has recorded such undesirable sequelae in the literature

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10

Bone Tumors of the Shoulder Joint

GENERAL CONSIDERATIONS

Introduction

Neoplasms benign and malignant are encountered frequently in the shoulder region Codman s Survey of the Registry of Bone Sarcoma (1922) disclosed that 13 5 per cent of all bone tumors were found in the bones of the shoulders osteogenic sarcoma of the head of the humerus being most commonly found

The noted frequency of tumors in this region makes it imperative to discuss them as a group, to sharpen our focus in the diagnosis and the treatment of shoulder disorders This chapter does not aim to present in detail the many controversial theories of histology and origin of tumors but is concerned primarily with the recognition and the management of such lesions. Generally tumors of the shoulder do not differ from those in other parts of the body However it should be recognized that accurate diagnosis and adequate treatment based on sound clinical and surgical judgment are more important in managing lesions in this than other parts of the body An error here may mean the loss of a highly specialized extremity and seriously impair the patient s economic status

As in lesions affecting other parts of the skeleton lesions in the bones of the shoulder girdle must be investigated thoroughly to establish their identity The skill and the rapidity with which this is done may have a direct bearing upon the ultimate outcome of the case Even today when both laymen and physicians are reminded constantly of the value of early diagnosis and treatment of cancer many instances of cancer come to a sad end because the patient or the physician fails to bring about an early diagnosis and adequate therapy

Classification of Bone Tumors

Classification of tumors of bone remains a confusing problem. This stems from a lack of agreement among investigators on the basis of a classification Workers approach the perplexing subject from divergent viewpoints some attempt to classify neoplasms and other bone lesions on their anatomic and histologic characteristics others believe that a classification should denote

CLASSIFICATION OF BONE TUMORS (COLEY)

Malignant	*Benign*
Fibrosarcoma of bone	Nonosteogenic fibroma of bone
Osteogenic sarcoma	Osteoma
	Osteoid Osteoma
	Exostosis
Primary Chondrosarcoma	Chondroma
Secondary chondromyxosarcoma	
Malignant giant-cell tumor	Benign giant-cell tumor
	Benign chondroblastoma (Codman's epiphyseal chondromatous (giant-cell tumor)
	Unicameral bone cyst
Endothelioma (Ewing's sarcoma)	Cavernous angioma
Angiosarcoma	Plexiform angioma
Myeloma: plasma-cell myeloma, myelocytoma, erythroblastoma, lymphocytoma	
Reticulum-cell sarcoma	
Liposarcoma	

pathologic or radiographic features of the lesions.

Happily however there is a trend to crystallize a classification of primary bone neoplasms in accordance with the predominant cell or tissue found in the tumor and arising from the undifferentiated germ cells of bone This trend is being carried still further to include tumors from the accessory tissues of bone (bone marrow reticulo-endothelial system and marrow connective tissue)

Coley modified the revised classification of the Registry of Bone Sarcoma of the American College of Surgeons to include benign and malignant neoplasms

This revised classification has placed malignant neoplasms derived from cartilage in a separate group The osteogenic group is subdivided further in accordance to the location and the radiographic features of the tumors The subdivisions are

1 Medullary and subperiosteal
2 Telangiectatic
3 Sclerosing
4 Periosteal
5 Fibrosarcoma
   A. Medullary
   B Periosteal
6 Capsular and parosteal

DIAGNOSIS OF BONE TUMORS

HISTORY

A carefully taken history may give information of great value in arriving at a correct diagnosis In many instances it will establish the diagnosis in others it will contribute important data which together with other diagnostic aids, will permit the diagnosis to be made Rapidly growing tumors regardless of their location or the patient's age must be considered very malignant Slowly growing tumors are less malignant Increase in size of a tumor previously existing for a long time without evidence of activity is usually indicative of secondary malignant changes in a benign lesion.

AGE OF PATIENT

Age is always an important item in evaluating bone tumors particularly osteogenic sarcoma Badgley and Batts noted that the greatest number of osteogenic sarcomas occur in the second decennium (40 of 80 cases reported) According to Christensen two-thirds of 441 cases of bone sarcoma occurred between 10 and 30 and one third over 30 years also, that very young and

very old people are rarely victims of bone sarcoma

Codman emphasized that osteogenic sarcoma in patients around 50 is usually indicative of Paget's disease with secondary sarcomatous changes In a review of 17 sarcomas of the upper end of the humerus listed in the Bone Sarcoma Registry he found 3 cases around 50 years of age All three had Paget's disease of the bone Bird records that 14 per cent of all cases of Paget's disease develop bone sarcoma. Bone cysts occur before closure of the epiphyseal disk, while giant-cell tumors are found after the epiphysis has united. Plasma-cell myeloma is rarely encountered under the age of 40, metastatic lesions are usually found past middle life

Pain

In the early stages of a malignant bone neoplasm pain is an exceedingly variable symptom. It may be mild and present only on activity or intermittent so that its seriousness is not appreciated by the patient or the physician. As a rule pain comes on insidiously Occasionally its onset is sudden and may be accompanied by a systemic reaction similar to an infectious process such as osteomyelitis This is particularly true of Ewing's tumor and highly malignant rapidly growing osteogenic sarcomas

Later the pain becomes more constant and often is referred to as boring in character It is accentuated by activity and is more pronounced at night Usually it is localized over the affected portion of the bone occasionally it is referred to areas distal to the site of the lesion. Pain in malignant lesions of the upper end of the humerus is referred not infrequently to the region of the deltoid insertion or to the inferior angle of the scapula Expansile lesions such as giant-cell tumors of the upper end of the humerus are accompanied often by a steady constant dull deep-seated pain

Benign tumors are rarely painful unless they interfere with the excursion of muscles overlying them or act as a mechanical barrier to normal joint motion In many instances, the first indication of the existence of a benign cystic lesion may be fracture of the bone Giant-cell tumors are the exception, pain of varying degrees is usually present. Primary malignant tumors usually are accompanied by pain, while metastatic lesions may fail to produce pain

Injury

In a large group of cases trauma antedates the symptoms and the local findings. Its significance is of doubtful value, except that it may serve to make the patient aware of an existing lesion. It is generally accepted that a single injury, regardless of the degree of severity is not the prime causative agent responsible for the development of malignant neoplasms of bone A detailed account of the trauma, e.g., its time and manner of occurrence severity and demonstrable local evidence of injury at the time of examination should be noted and recorded Such data may be of importance should the case assume medicolegal proportions.

Loss of Function

Tumors in the region of the shoulder rarely produce marked disability except in the late stages of the disease. Large and rapidly growing lesions of the scapula and the upper end of the humerus may be accompanied by spasm and contracture of the adductor muscles, e g the pectoralis major and minor the latissimus dorsi and the teres major muscles This results in marked restriction of glenohumeral and scapulothoracic motion and total disruption of the capulohumeral rhythm.

Past History

Past history will elicit the presence or the absence of repeated trauma and strains to the involved area also the previous existence of infectious processes which might primarily or secondarily affect the osseous system Notably among the infectious processes are tuberculosis osteomyelitis, syph

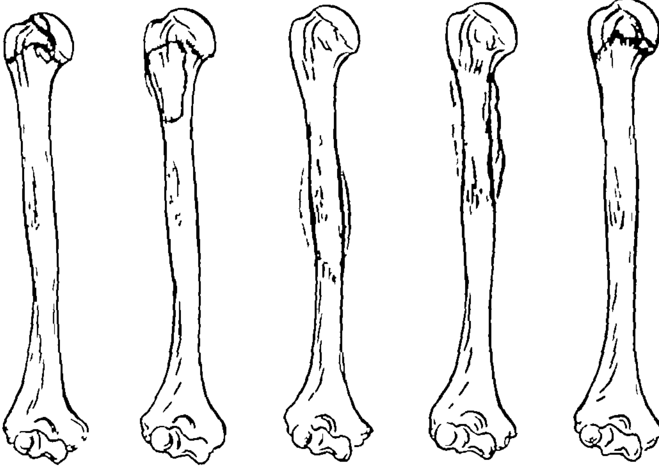

FIG 290 Common sites of primary tumors in the upper end of the humerus. (A) Giant-cell tumor (B) Bone cyst (C) Ewing s tumor (D) Osteogenic sarcoma. (E) Chondrosarcoma.

ilis typhoid fever and brucellosis Metabolic and deficiency disorders such as gout rickets and scurvy are capable of producing bone lesions

It is of utmost importance in older individuals to establish the presence or the absence of Paget s disease of bone and tumors of any part of the body either past or present Metastatic bone lesions may occur many years after the removal of carcinoma of the breast or the thyroid gland One case exhibited metastasis to the head of the humerus eight years after the removal of a carcinoma of the breast by radical mastectomy

Site of Tumor

Knowledge of the predilection of tumors of bone is a valuable aid in making a diagnosis Osteogenic sarcoma is encountered more frequently in the humerus than any of the other bones of the shoulder girdle Solitary bone cysts are observed most frequently in the diaphysis close to the metaphysis giant-cell tumors in the epiphyseal region (usually after ossification of the epiphyseal plate) The upper end of the humerus is a common site for chondrosarcomas Ewing s tumors most frequently involve the shafts of long bones, while osteogenic arcomas involve the ends of the shafts, the metaphyseal region (Fig 290)

Objective Findings

A careful physical examination in most instances discloses pertinent clinical features upon which a presumptive diagnosis can be made The skin over a neoplasm usually exhibits numerous dilated venous channels its color is distinctive, being a reddish, dusky hue In moderate and far advanced chondrosarcomas or osteogenic sarcomas in

Fig 291 Enlargement of right extremity resulting from obstruction of venous and lymphatic circulation by hemangiosarcoma of the right scapula. The patient died of generalized metastasis (T A Shallow Jefferson Medical College.)

volving the bones of the shoulder girdle the characteristic configuration of the point of the shoulder is lost the bony landmarks being obscured by the tumor mass and the surrounding soft tissue reaction

Palpation of the tissues around the lesion often discloses increased local temperature especially in rapidly growing highly vascular lesions Unless the overlying tissue is involved the skin is freely movable over the tumor mass. The skin may be thin and stretched tightly over the mass occasionally ulceration occurs and the tumor may fungate through the skin This seldom occurs in bone sarcomas, unless an ill performed biopsy has been done it is observed more commonly in carcinomas

The size and the shape of tumors in the region of the shoulder as in other parts of the body vary greatly Chondrosarcomas are usually the largest tumors affecting this region Generally tumors arising in the medullary and cortical portions of bone encounter greater resistance to growth and expansion than those arising from the surface of bone or beneath the periosteum, the latter group are faster-growing lesions and reach greater dimensions Interference with the venous and lymphatic circulation may result in pronounced enlargement of the extremity distal to the lesion (Figs 291 and 292) The distortion may approach such proportions as to destroy completely the functional usefulness of the arm. However size does not indicate the malignant or benign character of a tumor It is generally recognized that many small tumors may not be detected until after there is evidence of metastasis

Pulsating Tumors

Highly vascular tumors may pulsate. However pulsation is a relatively rare feature of bone tumors, observed in lesions involving the ends of long bones and (less frequently) in lesions of the shafts. Osteolytic metastatic lesions from renal and thyroid cancer may produce a pulsating tumor Codman was of the opinion that pulsation of a tumor mass destroys the surrounding bone and causes expansion of the remaining thin bony shell Extension of the tumor down the medullary canal is restrained by the pulsating bone marrow

The number of pulsating giant-cell tumors reported in the literature is exceeding small Except for the greater rapidity of growth and greater tendency toward recurrence after therapy either by surgery or irradiation these lesions in no way differ histologically from nonpulsating giant-cell tumors

Body Reaction

As previously indicated a malignant osteogenic neoplasm may be ushered in with all the clinical manifestations of an acute infection. It is common knowledge that many cases of Ewing s tumor have been subjected erroneously to operative procedures under the diagnosis of acute osteomyelitis.

Roentgenographic study may fail to disclose the true nature of the lesion

Because of the associated intense pain and the characteristic roentgenographic feature of localized increased bone density simulating a localized bone abscess, osteoid osteoma also has been operated upon under such mistaken diagnoses as Brodie s abscess and Garre s disease One instance of osteoid osteoma was curetted at one operation and drilled at another before the true nature of the disease was suspected The symptoms were relieved only after the third operation, at which time a block resection was done on the bone which contained the nidus To date, *no osteoid osteoma of the upper one third or head of the humerus has been reported* Ten cases with involvement of the shaft of the humerus distal to its upper third are on record

As a rule the general health of a patient with sarcoma is better than in carcinoma except in the terminal phases In carcinoma there is always demonstrable anemia of varying degrees which becomes more marked as the tumor progresses Many of the patients become extremely apprehensive and irritable as a result of the severe pain which often interferes with their sleep

Roentgenographic Studies

Roentgenographic examination is even more important than physical examination and second only in importance to histologic study of bone lesions, in arriving at a diagnosis In many instances carefully taken roentgenograms in anteroposterior lateral and oblique views may give sufficient information to make a correct diagnosis It *must be pointed out that numerous and diverse interpretations may be derived from different roentgenologists* However one well versed in the characteristic features of bone lesions can make a correct diagnosis in a considerable number of cases and a tentative one in others

Codman was cognizant of the importance of radiographic studies about the shoulder when he stated

> Bone sarcoma is practically the only fatal lesion which arises in the shoulder We must learn to recognize it and to cure it. It should be our first thought in the case of a young patient complaining of a dull aching pain if any thickening of the bone were palpable or

FIG 292 Cystic degeneration occurring in the carpal and metacarpal bones of an individual with extensive lymphedema of the extremity following intensive radiation of a primary bone tumor in the upper end of the humerus. (H Ostrum, Philadelphia General Hospital)

the pain persisted for more than a week we should seek help from the X ray

Exposures other than the routine conventional ones mentioned may be necessary to give more accurate and detailed information Laminographic and stereoscopic exposures may add much pertinent information when more difficult diagnostic problems arise

It should be emphasized that it is often impossible to establish a diagnosis by roentgenographic study, even though many bone lesions demonstrate roentgenographically characteristic features which should reveal their identity (this is especially true of benign lesions) Some tumors of bone for example give rise to bizarre roentgenograms which defy the most competent roentgenologist It is interesting to note that many such lesions also usually exhibit histologic sections which fail to conform to any specific category Many lesions mimic the features of others making a correct diagnosis by roentgenographic survey alone almost impossible

Notable examples are syphilis of the bone which may be diagnosed erroneously as primary osteogenic sarcoma Ewing s tumor is often mistaken for acute osteomyelitis and vice versa single lesions of metastatic carcinoma to bone may be interpreted as primary osteologic bone sarcoma. In some cases it is impossible to differentiate Ewing s tumor from metastatic bone lesions of neuroblastoma osteoid osteoma may resemble a bone abscess or Garré s disease and myositis ossificans has been mistaken for periosteal sarcoma of bone Coley records an incidence of from 14 to 20 per cent error in roentgenographic diagnosis when checked by histologic examination

The character of ome bone lesions may point to generalized skeletal involvement which makes it imperative that a survey of the entire skeletal system be made This is true of such lesions as multiple myeloma parathyroid disease fibrous dysplasia of bone multiple exostosis and metastatic bone lesions. Roentgenographic study of the chest is an essential part of a diagnostic investigation of bone tumors Occasionally, the only evidence of the true nature of a bone lesion is the presence of metastatic nodules in the lungs Repeated examination of the chest at regular intervals should be made to check the diagnosis of a bone lesion and to follow the course of its behavior, regardless of the choice of therapy instituted

Laboratory Examinations

The role of laboratory investigations is progressively assuming greater proportions in the diagnosis of bone diseases Valuable contributions have been made to this aspect of bone study by Albright Reifenstein Woodard, Bodansky Gutman Kutscher and many others

The examinations which comprise a well rounded laboratory investigation are (1) complete blood count (2) Wassermann reaction of blood and spinal fluid (3) serum calcium level (4) serum phosphorous level (5) serum phosphatase level and (6) test for Bence Jones bodies in the urine Other tests that may reveal information of value are sugar determinations uric acid level which is elevated in gout and blood proteins level which may be greatly elevated in multiple myeloma

Alkaline phosphatase levels are normally high in growing individuals, and in normal reparative processes in which new bone is being formed such as in fractures. High values are also discernible in bone lesions characterized by new bone formation such as in osteogenic sarcoma osteoplastic metastatic carcinoma to bone and Paget s osteitis deformans Elevated phosphatase levels do not indicate any specific bone tumor or the malignant nature of bone lesions it is simply an indicator of new bone formation in the course of a normal reparative process or by a neoplastic primary or secondary bone lesion

In bone diseases exhibiting disturbance of calcium and phosphorous metabolism, the alkaline phosphatase values may be in-

creased, as in rickets, osteomalacia and hyperparathyroid disease

Generally osteolytic lesions arising from carcinoma do not cause a rise in the serum alkaline phosphatase level On the other hand in osteoplastic lesions, such as from cancer of the prostate gland, the level is invariably high In a study made by Coley, it was observed that 75 per cent of all metastatic bone lesions from the prostate were osteoplastic and the remainder disclosed some new bone formation Serum acid phosphatase is elevated in cases with metastatic bone lesions from prostatic cancer Some authorities believe that a high serum acid phosphatase level is pathognomonic of cancer of the prostate

Histologic Examination

In the great majority of cases the diagnostic steps previously mentioned will yield sufficient information to make a correct diagnosis But, in a small group, only a presumptive diagnosis can be arrived at The last and final aid at our disposal to establish a diagnosis is histologic examination of the suspected tissue Tissue may be obtained by surgical or aspiration biopsy

Aspiration biopsy is preferred to surgical biopsy in many cancer clinics because of its simplicity and its relative high incidence of satisfactory results. While it is a method that should be adopted in all tumor clinics it is not without some disadvantages Material obtained by aspiration may not be adequate to make a diagnosis There is always the possibility of disseminating tumor cells along the path of the needle or of producing hemorrhage within the tumor, thereby favoring metastasis The experience of Coley and Snyder with this method is significant. They recorded that in 568 aspiration biopsies of bone on 474 individuals there were no immediate complications and no evidence suggesting that the procedure had caused more rapid development of metastasis. Also in 67 5 per cent of 385 cases of primary and metastatic bone neoplasms a specific diagnosis was established by aspiration biopsy 82 per cent of these cases yielded sufficient tissue to permit a diagnosis in 14.5 per cent the tissue was not identified and in 1 case a benign lesion was diagnosed as a malignant tumor

Aspiration of the iliac crest for bone marrow is gradually displacing sternal puncture formerly a valuable diagnostic procedure in cases of metastatic carcinoma multiple myeloma and leukemia Erf is of the opinion that marrow from the iliac crest permits an earlier diagnosis in the above lesions and gives a higher incidence of specific diagnoses than sternal puncture

Surgical biopsy is still the method of choice in some institutions In some cases it is the only method whereby tissue can be obtained for histologic examination It is a procedure which should not be taken lightly and should be performed only by surgeons well versed in surgical technic and in the handling of tissues Whenever possible the operation should be performed under tourniquet after the desired tissue is obtained the wound is closed in layers No incision in a suspected malignant tumor should ever be left open or drained Closure as described above should be carried out even in the event that severe hemorrhage demands packing of the wound By so doing the chances of disseminating tumor cells and fungation of the tissues are minimized. In spite of the greater hazards of surgical biopsy, it yields more material for examination and a greater incidence of specific diagnoses than the aspiration method It always should be performed when any radical surgical procedure is contemplated

GIANT CELL TUMOR

Introduction

Giant-cell tumor is now definitely established as a benign disease of the bone primarily affecting the ends of the shaft of long bones Many limbs were sacrificed needlessly until its true nature was recognized Credit goes to Cooper Paget Nilater later to Gross Stewart Coley Bloodgood and

the pain persisted for more than a week, we should seek help from the X ray

Exposures other than the routine conventional ones mentioned may be necessary to give more accurate and detailed information Laminographic and stereoscopic exposures may add much pertinent information when more difficult diagnostic problems arise

It should be emphasized that it is often impossible to establish a diagnosis by roentgenographic study, even though many bone lesions demonstrate roentgenographically characteristic features which should reveal their identity (this is especially true of benign lesions) Some tumors of bone, for example give rise to bizarre roentgenograms which defy the most competent roentgenologist. It is interesting to note that many such lesions also usually exhibit histologic sections which fail to conform to any specific category Many lesions mimic the features of others making a correct diagnosis by roentgenographic survey alone almost impossible

Notable examples are syphilis of the bone which may be diagnosed erroneously as primary osteogenic sarcoma Ewing s tumor is often mistaken for acute osteomyelitis and vice versa single lesions of metastatic carcinoma to bone may be interpreted as primary osteologic bone sarcoma In some cases it is impossible to differentiate Ewing s tumor from metastatic bone lesions of neuroblastoma osteoid osteoma may resemble a bone abscess or Carré s disease, and myositis ossificans has been mistaken for periosteal sarcoma of bone Coley records an incidence of from 14 to 20 per cent error in roentgenographic diagnosis when checked by histologic examination

The character of some bone lesions may point to generalized skeletal involvement which makes it imperative that a survey of the entire skeletal system be made This is true of such lesions as multiple myeloma parathyroid disease fibrous dysplasia of bone multiple exostosis and metastatic bone lesions Roentgenographic study of the chest is an essential part of a diagnostic investigation of bone tumors. Occasionally, the only evidence of the true nature of a bone lesion is the presence of metastatic nodules in the lungs Repeated examination of the chest at regular intervals should be made to check the diagnosis of a bone lesion and to follow the course of its behavior, regardless of the choice of therapy instituted

Laboratory Examinations

The role of laboratory investigations is progressively assuming greater proportions in the diagnosis of bone diseases. Valuable contributions have been made to this aspect of bone study by Albright Reifenstein, Woodard Bodansky Gutman Kutscher and many others

The examinations which comprise a well rounded laboratory investigation are (1) complete blood count (2) Wassermann reaction of blood and spinal fluid (3) serum calcium level (4) serum phosphorous level (5) serum phosphatase level and (6) test for Bence Jones bodies in the urine Other tests that may reveal information of value are sugar determinations uric acid level which is elevated in gout and blood proteins level which may be greately elevated in multiple myeloma.

Alkaline phosphatase levels are normally high in growing individuals and in normal reparative processes in which new bone is being formed such as in fractures High values are also discernible in bone lesions characterized by new bone formation such as in osteogenic sarcoma, osteoplastic metastatic carcinoma to bone and Paget s osteitis deformans Elevated phosphatase levels do not indicate any specific bone tumor or the malignant nature of bone lesions it is simply an indicator of new bone formation in the course of a normal reparative process or by a neoplastic primary or secondary bone lesion

In bone diseases exhibiting disturbance of calcium and phosphorous metabolism, the alkaline phosphatase values may be in-

The traumatic theory is the one most generally accepted

Codman believed that rupture of a nutrient artery which fails to clot was the origin of all giant-cell tumors From this nidus arises a pulsating mass of tissue which produces resorption of the adjacent bony cancellous trabeculae The mass extends centrally because the cancellous bone is less resistant than cortical bone Extension of the tumor into the shaft is prevented by the pulsating bone marrow

Geschickter and Copeland contend that trauma following subperiosteal hemorrhage interrupts normal blood supply to the cortex of the adjacent bone This results in increased osteoclastic activity in the subcortical region of the traumatized cortex and finally by hyperplasia of osteoclasts, a tissue designated giant-cell tumor is formed

Macroscopic Pathology

Macroscopic examination of early tumors discloses their subcortical origin They are eccentrically located, tending to invade the cancellous bone centrally, while the more-resistant cortical bone acts as an effective barrier to peripheral expansion of the tumor More advanced lesions reveal expansion of the epiphyseal region with marked thinning of the cortical shell which may be perforated in several places (Fig 293) The periosteum tends to limit the tumor mass when the continuity of the cortex is broken even this last barrier may be broken in very aggressive tumors, causing invasion of the surrounding soft tissue The tumor rarely invades the joint cavity the articular cartilage resists invasion It is not uncommon to find the cartilage still intact sitting like a cap on a mass of tumor tissue (Fig 293) even in the most advanced lesions, with total destruction of all bony elements Extension into the shaft does not proceed too far beyond the metaphyseal region, apparently the pulsating bone marrow tends to limit the advance of the tumor Fibrous tissue proliferation in this region also restrains the tumor from advancing into the shaft

The tissue varies in color and consistency in different tumors Usually it is friable disintegrates readily bleeds freely and ranges in color from red to black occasionally, it is firm and puttylike and of a grayish white color Fibrous trabeculae—some coarse others fine—are often encountered throughout the tumor appearing to extend into the substance of the tumor from its periphery At operation the tumor may be very vascular as evidenced by marked generalized oozing and the presence of large spurring vessels Frank hemorrhage may be difficult to control in such lesions Other tumors may be avascular, permitting curettage without difficulty

Microscopic Pathology

The histologic picture varies in different tumors or in different areas of the same tumor, depending upon the stage of the neoplasm's development and the secondary changes present in the tumor tissues In tumors exhibiting no (or only minimal) secondary alterations, the tumor tissue comprises a characteristic stroma made up of mononuclear spindle or ovoid cells, varying numbers of multinuclear giant cells and small amounts of intercellular collagenous substance consisting of fine fibers.

The ratio of spindle to ovoid cells varies in different tumors These cells possess a single round or elongated nucleus which occupies a considerable portion of the cell Each nucleus contains a well-defined central nucleolus and a moderate amount of evenly distributed chromatin material As a rule, the ovoid cells are found in greater numbers than the spindle cells The outline of the cytoplasm of the stromal cells may be indistinct and exhibit delicate cytoplasmic processes Jaffe records that the most plausible origin of stroma cells is from mesenchymelike supporting connective tissue of the marrow

Irregularly distributed throughout the stroma are the multinucleated giant cells, measuring from 30 to 100 or more microns The number of giant cells in each field

FIG 293 Giant-cell tumor involving the entire upper end of the shaft of the humerus in a female aged 23 Note the expansile nature of the tumor only a thin cortical shell remains. No bony shell is visible on the inner aspect of the tumor At operation it was noted that the tumor was limited in this region by the thickened periosteum only Observe the intact cartilage on the superior aspect of the head

others for recognizing and emphasizing the benignity of this neoplasm. However it is now known that giant-cell tumors occasionally take on malignant characteristics and may metastasize to the lungs Such malignant changes have been noted when tumors were first seen and before any form of therapy had been instituted The majority of malignant giant-cell tumors have been noted following some form of therapy usually irradiation

Age and Sex

Giant-cell tumors are rarely found in young children or in individuals past middle life, the highest incidence in any series recorded is in the third decennium. Geschickter and Copeland report that 40 per cent of all giant-cell tumors occur in the third decade Coley records 48 out of 124 cases occurring between the ages of 21 and 30 years, 78 in 124 being between the ages of 21 and 40 years

There appears to be no predilection as to sex. Males and females are affected about equally

Site

The proximal end of the humerus ranks fourth in frequency More common sites in order of frequency are the distal end of the femur, the proximal end of the tibia and the distal end of the radius.

Although giant-cell tumors are primarily solitary neoplasms of the cancellous portions of tubular bones they occur in all bones of the body, including the skull Giant-cell tumors usually begin in the subcortical portion of the epiphysis and by gradual expansion and destruction of the less-resistant cancellous bone occupy a more central position Occasionally the tumors are completely eccentric, appearing to develop beneath the periosteum such tumors are designated as subperiosteal giant-cell tumors. Subperiosteal giant-cell tumors have been reported as arising from the shaft of the long bones at a distance from the epiphyseal region Some investigators are of the opinion that the latter group is a distinct entity these tumors being sequelae of subperiosteal hematoma

Etiology

Numerous theories have been advanced to explain the origin of giant-cell tumors. Barrie's theory of hemorrhagic osteomyelitis disproved by Stewart (1922) has been discarded There are still supporters of the neoplastic theory some of whom postulate that the tumor arises from marrow cells others believe that it originates from and consists of bone formative cells (Willis) which possess osteoclastic characteristics

irregular whorled arrangement, demonstrating uniformly signs of atypism. These tumors are outright malignant neoplasms and usually metastasize to the lungs. They usually represent malignant transformations of Grades I and II but occasionally begin as Grade III tumors (Fig. 294).

Clinical Features

Giant-cell tumors are usually encountered in the third decade of life. Usually a definite history of trauma to the shoulder can be elicited. Pain of varying degrees is the cardinal symptom. As a rule the pain is not severe, may be intermittent and is often referred to the insertion of the deltoid muscle or the posterior region of the shoulder. At first the pain is often described as "rheumatic" in nature. It is accentuated by activity and relieved by rest. Motion at the shoulder joint in the early phases of the disease may not be impaired materially.

Pain becomes more severe and constant as the tumor progresses. The patient holds the arm to the side and protects it against unguarded movements. Contracture and shortening of the adductor muscles follow, producing greater restriction of motion. No case under the author's personal observation involved a completely frozen shoulder; however, motion is usually possible only below the horizontal. Pain interferes with

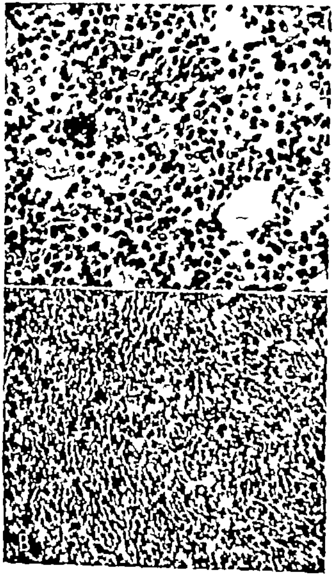

Fig. 294B. (*Top*) Tissue from a giant-cell tumor already classified as belonging to Grade II (× 285). The lesion occupied the lower end of a femur in a man of 36. There was no preoperative irradiation of the tumor. Note the compaction of the stromal cells and the presence of multiple nuclei in some of them. More of the stromal cells showed mitoses than show them in a tumor of Grade I. Despite postoperative irradiation, the lesion progressed and two and one-fourth years later the histologic picture had changed completely, the lesion having become frankly malignant.

(*Bottom*) Tissue from a giant-cell tumor of Grade II that occupied the lower end of a femur in a 23-year-old woman (× 90). The tissue shown represents material obtained from the lesion through curettement some time after a thorough course of radiation therapy had failed to control its progression. Subsequently, the lesion became infected and fungated, and the limb was ablated. Note that the field illustrated contains numerous densely compacted spindle-shaped stromal cells but that hyalinization of the stroma, which would indicate an irradiation effect, is absent. Note also that hardly any giant cells are to be seen in the photomicrograph. In other fields of the tumor, however, they were very numerous and the histologic architecture altogether so characteristic that there could be no doubt that one was dealing with a giant-cell tumor in spite of the concomitant presence of more ominous looking areas like the one shown. (Jaffe et al.: Arch. Path., 30: 1004.)

varies, generally, the number demonstrable in the low-power field ranges from 10 to 35 cells The nuclei of typical giant cells generally occupy a central position in the cell their number varying from 15 to 100 or more in each cell They display a remarkably close resemblance to the nuclei of ovoid stromal cells Some workers are of the opinion that giant cells are formed by fusion of the stromal cells

Collagen fibers are not abundant in uncomplicated giant-cell tumors When the stromal cells exhibit a loosely arranged pattern the collagenous material is more abundant than in a compact arrangement of the stromal cells Vascularity of the tumor tissue is also a variable feature the vascular spaces are thin walled composed of flattened endothelial cells Tumor cells are frequently found in close relation with the vessel walls Areas of hemorrhage are frequently encountered scattered throughout the tumor

Jaffe believes that a typical, uncomplicated giant-cell tumor discloses a characteristic stromal pattern Change in this stroma indicates the aggressiveness of the tumor certain features pointing to a frankly malignant giant-cell tumor He describes three grades of aggressiveness

Grade I is the least aggressive In this group there is a loose arrangement of the stromal cells with no appreciable atypism of the stroma cells Grade II is more aggressive Tumors in this category tend to recur and finally may assume the characteristics of Group III The stroma cells are in greater abundance than in Group I forming a compact stromal pattern and disclosing definite manifestations of atypism Grade III is characterized by a dense compact stroma with an

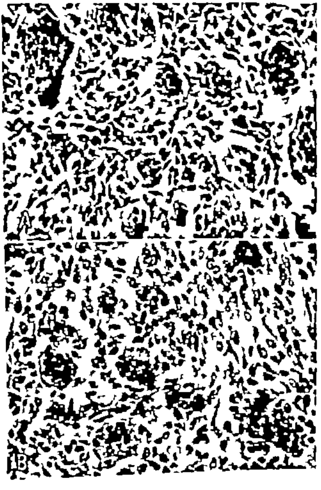

FIG 294A. (*Top*) Tissue from a giant-cell tumor of Grade I that occupied the head and neck of a humerus in a woman of 30 (× 275) There was no preoperative irradiation of this tumor Note the abundance of large giant cells and the predominantly spindle-shaped and not closely compacted stromal cells between them. The stromal cells presented few mitoses and no evidences of atypism Altogether this histologic picture represents what can definitely be called a benign' giant-cell tumor and indeed curettage and postoperative irradiation of the lesion were followed within a year by substantial repair of the affected area.

(*Bottom*) Tissue from a giant-cell tumor still properly classifiable as belonging to Grade I but no longer so clearly benign as the tumor above (× 245) The lesion occupied the head and neck of a femur in a woman of 22 There was no preoperative irradiation of the tumor Note that the giant cells are rather abundant between the stromal cells and that the latter are abundant but not closely compacted The stromal cells do not show appreciable atypism but here and there some of them have large nuclei and an occasional one even has two nuclei. In this case, postoperative irradiation was not followed by prompt clinical improvement. Eventually we lost sight of this patient, as she left the country (Jaffe et al. Arch. Path. 30 1002)

Fig 295 Giant-cell tumor in female, aged 26 Observe pronounced expansion of the upper end of the humerus the remaining cortical shell is thin on the outer aspect of the humerus and absent on the inner aspect A cartilaginous cap still remains intact the tumor is traversed by trabeculae of varying thicknesses giving the tumor mass a bubble-like appearance.

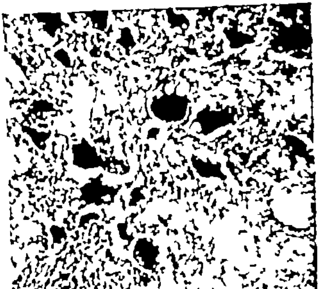

Fig 296 Tissue obtained from giant cell tumor depicted in Figure 295 The stroma comprises mononuclear spindle and ovoid cells and small amounts of intercellular collagenous substances consisting of fine fibers. Many multinucleated giant cells of varying sizes are distributed irregularly throughout the stroma [Photomicrographs (× 160 and × 320)]

served in the early states Later, with resorption of the cancellous bone, the lesion occupies a more central position fine or coarse trabeculae may traverse the tumor, giving it a bubblelike pattern the upper end of the humerus expands its cortical shell becomes thin and it may even show evidence of perforation by a break in its continuity Generally, the tumor does not extend far beyond the limits of the metaphysis into the shaft. Advanced lesions exhibit total destruction of all the bony elements in this region the limits of the tumor being maintained by a barely perceptible thin bony shell and a thickened periosteal sheath. Occasionally only the periosteal tube remains in certain areas around the tumor The cartilage resists joint invasion and becomes calcified and new bone may form on its under surface so that in the roentgenograms it is discernible as a thin smooth line of increased density (Fig 295) Characteristic of this lesion at no time is there radiographic evidence of periosteal reaction, soft tissue mass or swelling In the event of fracture, displacement of the fragments is not pronounced No evidence of

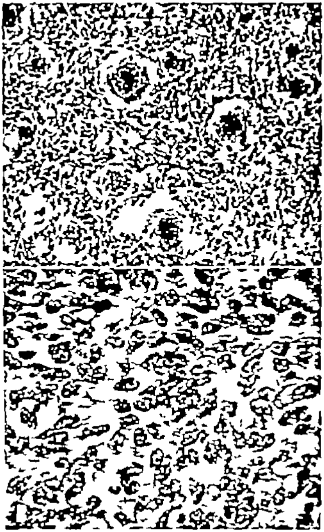

Fig 294C (*Top*) Tissue from a giant cell tumor of Grade II which occupied the lower end of a femur of a 44-year old man (× 150) Radiation was not given preoperatively but was used after *thorough curettage Nevertheless there* was a recurrence associated with infection and fungation necessitating ablation of the limb about one and a half years later The field illustrated is from *the tissue* originally curetted out. Note between the giant cells, the densely compacted stromal cells in a somewhat irregular whorled arrangement. In the field illustrated these cells, when studied in detail did not present much atypism but in other fields (*below*) they did This shows the necessity for studying details of the stromal cells *from many* areas prognosing the lesion by its most ominous-looking parts.

(*Bottom*) Stromal cell field showing atypism from same tumor (× 550) Several of the cells *contain* two or more nuclei the nuclei in general are large and many show hyperchromatism (Jaffe et al Arch. Path. 30 1006)

the patient s sleep and becomes excruciating if the individual lies on the affected shoulder Occasionally, swelling of the extremity distal to the lesion is demonstrable Spontaneous fracture may occur, all symptoms now become more pronounced and functional impairment of the extremity is increased

Physical Findings

During the early stages of the disease no physical evidence of a tumor may be apparent. Impairment of normal movements at the shoulder joint is manifest early and increases with progression of the tumor Except in very thin individuals swelling is not readily visible or palpable because the head *of the humerus is almost completely covered* with the fleshy deltoid muscle. Pressure *over the upper end of the humerus and over* the tuberosity of the humeral head invariably *elicits complaints of tenderness*

In the later stages with expansion of the upper end of the humerus the affected shoulder appears fuller and more prominent when compared with the normal side. Palpation reveals a smooth, symmetric enlargement of the upper end of the humerus All movements except within a small range, are painful Pressure over the distended portion of the bone shows considerable tenderness to be present The skin and the muscle are freely movable over the involved bone and exhibit no significant diagnostic features. Pulsation is an exceedingly rare sign *but it* may occur Up to 1946 only seven cases of *pulsating giant-cell tumors were reported in* the literature this feature being more com*monly associated with thyroid or renal* metastasis to bone

Roentgenologic Features

Certain characteristic radiologic features of a giant-cell tumor plus the fact that it occurs in the epiphyseal region of the humerus in a specific age period (usually the third decade) render roentgenographic interpretation of the lesion relatively *simple.* Only an eccentrically placed radiolucent *area in the epiphyseal region may be ob-*

stroma of the tumor Clinical and roentgenologic features are not sufficient to establish a positive diagnosis Giant cell tumors which undergo malignant transformation following irradiation, surgery, or both manifest their true character by recurrence of symptoms at varying periods following the initial therapeutic measures Microscopic study confirms the diagnosis It is obvious, of course, that clinical evidence of pulmonary metastasis following the treatment of a supposedly benign giant-cell tumor confirms the malignant nature of the lesion

Osteogenic Sarcoma. Medullary or central osteogenic sarcoma may arise occasionally in the proximal end of the humerus The neoplasm may run a clinical course similar to that of giant-cell tumor Roentgenographically a radiolucent lesion is demonstrable in the epiphyseal region consistent with an osteolytic process no new bone formation may be discernible Hence, even by roentgenographic study the malignant lesion may not differ essentially from giant-cell tumor Histologic examination is the only diagnostic aid which will establish the identity of the lesion

Epiphyseal Chondromatous Giant Cell Tumor This rare benign lesion first described by Codman (1931) is located in the greater tuberosity of the head of the humerus It occurs before ossification of the epiphyseal plate in a younger age group than giant-cell tumors. The tumor does not extend beyond the epiphyseal cartilage of the articular head No trabeculations are discernible in the substance of the tumor which has a "cotton wool appearance in the roentgenogram. These tumors run a mild clinical course microscopic examination identifies them readily and reveals that a considerable portion of these tumors consist of cartilage

Hyperparathyroidism (Generalized Osteitis Fibrosa Cystica) Osseous lesions associated with hyperparathyroidism are nonneoplastic and multiple involving many of or all the bones of the body The lesion is more-or less diffuse chiefly affecting the haft of the bones Microscopic examination may fail to differentiate the lesion from giant-cell tumor because of the close similarity in the histologic sections

Fig 298 Giant-cell tumor depicted in Figure 295 4 months after curettage and packing of the remaining cavity with bone chips from the iliac crest and rib bone from the bone bank used as struts to prevent collapse of the cavity Observe that the rib struts are serving their function, and the bone chips are coalescing

Diagnosis is made readily by blood studies Normal serum levels of calcium phosphorus and phosphatase occur in giant cell tumor while the serum calcium and phosphatase are elevated and the phosphorus is lowered in generalized osteitis fibrosa cystica

Metastatic Carcinoma. Occasionally isolated metastatic bone lesions of the upper end of the humerus may occur particularly from renal or thyroid cancer Roentgenograms may reveal an osteolytic and even expansile lesion The lesion is pictured as a radiolucent area in the bone with no evi

FIG 297 Osteolytic metastatic breast carcinoma in upper end of the humerus resembling a giant-cell tumor in a female 42 years of age. (B P Widmann and J C Howell, Philadelphia General Hospital.)

repair is discernible clinically or radiographically

Although the above features are more or less indicative of a giant-cell tumor the diagnosis can only be a presumptive one Occasionally osteolytic metastatic lesions and central osteogenic sarcomas in the head of the humerus depict radiographic features closely resembling those described above (Fig 297)

DIAGNOSIS

The age of the patient and the location of the tumor are the two most significant factors in establishing the diagnosis of giant cell tumors. Nevertheless there are several entities, neoplastic and nonneoplastic which may resemble closely the characteristics of these tumors both clinically and roentgenographically It becomes apparent that before any therapeutic measures are instituted the diagnosis of giant-cell tumor should be confirmed first by histologic examination

Osseous lesions which are more apt to be confused with giant-cell tumor are (1) bone cyst, (2) malignant giant-cell tumor (3) medullary (central) osteogenic sarcoma (4) epiphyseal chondromatous giant-cell tumor (Codman s) (5) hyperparathyroidism and (6) metastatic carcinoma.

Bone Cyst (Solitary Osteitis Fibrosa) The features of bone cysts which resemble giant-cell tumors are usual location in the upper end of the humerus close to the epiphyseal plate expansive tendencies (the transverse dimensions of the shaft increase and the cortical shell may become so thin that in many instances fracture ensues), histologic structure and benign nature

Giant-cell tumors may be differentiated from bone cyst by their occurrence in an older age period after epiphyseal ossification is completed While giant-cell tumors are located in the region of the epiphysis proximal to the epiphyseal plate, bone cysts occur in individuals of an earlier age group in whom the epiphyseal line is still open the lesion arising on the diaphyseal side of the metaphysis.

The clinical course of bone cysts differs from that of giant-cell tumors in their mildness. Many bone cysts cause no symptoms and are discovered only accidentally or when a fracture of the humeral shaft occurs Following fracture there is evidence of an active reparative process which may not only heal the fracture but may obliterate the cyst Such a reparative process never has been observed following pathologic fracture in giant-cell tumors

Histologic examination may be very confusing because of the close resemblance between giant-cell tumors and bone cysts. The diagnosis depends chiefly upon the clinical course of the lesions the age of the patient, the location of the lesion in reference to the epiphyseal line and the roentgenographic features

Malignant Giant Cell Tumors. The malignant nature of a giant-cell tumor can be definitely detected only by microscopic examination which discloses the sarcomatous

and surgery However, there is much dis agreement as to which is the better method Some investigators contend that treatment by roentgen rays causes less impairment of joint function and is followed by fewer re currences. On the other hand, investigators favoring surgery maintain that it is fol lowed by shorter periods of disability that fracture is a common sequela of irradia tion, and that sarcoma may arise in irradi ated bone Coley notes that 25 per cent of the cases of giant-cell tumors of long bones treated by roentgen rays sustained patho- logic fractures

In general most workers favor the sur gical approach to this problem and employ irradiation only in tumors inaccessible to surgery, or those in which the neoplasm has advanced to a stage that complete surgical extirpation of the tumor tissue is impossible, or in cases in which there has been total dis- ruption of the joint with invasion of the tumor tissue into the joint cavity

The surgical procedures employed are curettage resection and amputation

Curettage. Giant-cell tumors in the upper end of the humerus are most amenable to curettage. Advanced lesions located in the humerus (Fig 298) can be treated by curet tage if they are present in weight bearing bones they are not acceptable for surgery because of subsequent severe impairment of joint function

TECHNIC OF CURETTAGE Adequate visu alization of all aspects of the upper end of the humerus is essential to evaluate cor rectly the extent of the lesion and to gain access to all tumor tissue.

The incision of Cubbins et al affords such an exposure (see Chap 11) The skin incision starts along the anterior border of the deltoid It is continued laterally on the inferior border of the clavicle, around the acromion process and along the inferior margin of the spine of the scapula

After complete hemostasis of the skin and the subcutaneous tissue the skin edges are fastened to towels by skin or towel clips to protect the wound edges from exposure and contamination The interval between the deltoid and the pectoralis major is de veloped proximally to the lower border of the clavicle taking care to avoid injury to the cephalic vein which is displaced medi ally with the edge of the pectoralis major muscle Next the deltoid muscle is reflected subperiosteally from the clavicle the acro- mion and the spine of the scapula Gently the entire muscle mass is displaced down ward thereby exposing the superior an terior lateral and posterior aspects of the glenohumeral joint

At this point emphasis should be placed on the care and the gentleness to be exer cised while obtaining the above exposure The soft tissues are covered and packed away from the involved bone by large hot sponges This will prevent contamination of the tissues by tumor material as it is being removed from the bone cavity

As a rule, the periosteal tube around the affected area of the humerus is intact It is divided longitudinally over the lateral as- pect of the greater tuberosity and reflected to either side The exposed thin cortical shell is perforated readily with a bone gauge and the opening is enlarged by rongeurs until all the areas within the cavity are accessible The tumor tissue is removed with a large curette taking care to avoid spilling An angular curette facilitates its removal from the roof of the cavity Curet tage is continued until normal healthy bone is reached The cavity is then flushed with normal saline solution and sucked dry This is done repeatedly until all loose tissue particles are removed The interior of the cavity is swabbed with a solution of satu rated zinc chloride and then the cavity is flushed again with normal saline solution Next, the cavity is packed tightly with a hot gauze sponge, left in situ while bone chips are being prepared to fill the defect

If the cortical shell of the humerus is intact and the defect is small the cavity is packed with small bone chips obtained from either or both the iliac crest and refriger

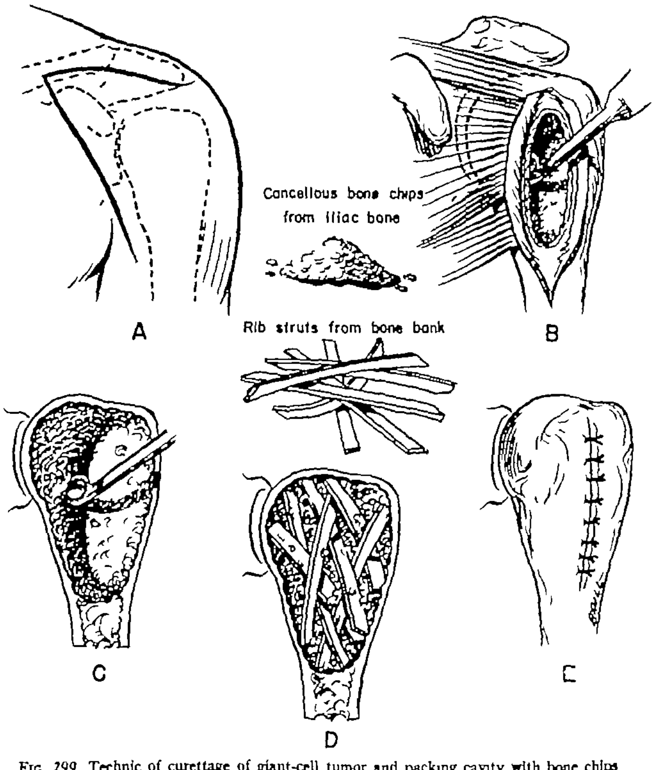

FIG 299 Technic of curettage of giant-cell tumor and packing cavity with bone chips and bone struts.

dence of new bone formation Diagnosis is made in accordance with the age of the patient (such lesions usually occur after the third decade), the general condition the demonstration of a primary lesion and microscopic examination of the tissue

Other osseous lesions that must be considered in a differential diagnosis are central chondroma and such tumors of the marrow cells as plasma-cell myeloma myelocytoma lymphocytoma and erythroblastoma.

Treatment

Essentially there are two methods of treatment for giant-cell tumors irradiation

EPIPHYSEAL CHONDROMATOUS GIANT-CELL TUMOR (CODMAN) [BENIGN CHONDROBLASTOMA OF BONE (JAFFE)]

INTRODUCTION

In 1931 Codman reported nine cases of this tumor which he found in the *Sarcoma Registry*. They paraded under such erroneous diagnoses as osteogenic sarcoma, chondrosarcoma and giant-cell tumors. He believed *these tumors were found only in the* region of the humeral head and that they were atypical giant-cell tumors. He wrote, "It is my belief that the peculiar structure of the head of the humerus makes the picture of giant-cell tumor so modified that typical cases do not often occur."

Since the first description of these lesions, they have been observed in the epiphyseal *regions of other long bones (lower end of* the femur and upper and lower ends of the tibia).

ORIGIN

Investigators differ as to the origin of epiphyseal chondromatous giant-cell tumors. Codman was of the opinion that this type of neoplasm was a benign giant-cell tumor arising *in the region of the tuberosities of* the head of the humerus at an age before complete ossification of the epiphyseal cartilages; that the "peculiar epitheloid cells which merge into a low grade type of cartilage cell" found in the tumor arose from the epiphyseal cartilage. Willis reports a case whose histologic structure supports the views of Codman.

On the other hand, Geschickter describes this lesion under the title of "chondroblastic tumors, benign and malignant," believing that these lesions arise from the metaphyseal side of the epiphyseal line and that the proliferating tissue was chondroblastic rather than composed of giant cells. Coley states that he knows of no verified instance of metastasis of this tumor and that in all the cases under his observation a cure was effected by conservative treatment. Jaffe and Lichtenstein (1942), convinced that the tumors have a cartilaginous origin, name the lesion "benign chondroblastoma of bone." Despite the inconsistencies as to its origin, it is generally conceded that this tumor is a definite entity possessing benign *characteristics*.

CLINICAL FEATURES

A survey of the cases reported in the literature discloses that the tumor occurs at a period in life when the epiphyseal plates of the upper end of the humerus are still open. Codman's nine cases ranged from 12 to 24 years of age. Males are affected more frequently than females. As previously mentioned, the region of the tuberosities of the upper end of the humerus, primarily the greater tuberosity, is involved most commonly. The onset and the clinical course are mild.

In Codman's series, the duration of the disease before treatment varied from 5 to 36 months. Trauma as an etiologic factor has not been proved, although it may make the patient cognizant of an existing lesion. Pain and restriction of shoulder motion are the cardinal symptoms. *Later swelling of* the upper end of the humerus may be *demonstrable; also tenderness over the greater* tuberosities may be elicited by firm pressure over this region. The benign nature of the neoplasm is evidenced by the fact that conservative measures result in a permanent cure.

ROENTGENOGRAPHIC FEATURES

Benign chondroblastomas usually occupy an eccentric position in the greater tuberosity. No reported tumor ever has extended beyond the proximal epiphyseal line to reach the articular cartilage of the head of the humerus, except in one case reported by Jaffe. These tumors present a "fluffy cotton wool look," are relatively small and are sharply demarcated from the surrounding normal bone by an area of increased density. Irregular areas of calcification scattered through the tumor may give it a mul

ated bone bank sources. Occasionally, after curettage the resulting defect is large, or the cavity collapses, after its contents have been removed as the result of dissolution of the cortical shell In these instances, it is advantageous to use 4 or 5 long strips of bone in the cavity as struts—placed parallel with the long axis of the shaft of the humerus—and to pack the spaces between the struts with tiny cancellous bone chips Rib bones split in halves make admirable bone struts for the purpose (A supply of rib bones is always available in the bone bank)

The incised periosteum is closed over the defect with interrupted cotton sutures, and the deltoid is reattached to its normal position. Several interrupted sutures close the interval between the deltoid and the pectoralis major muscles Finally, the skin edges are carefully approximated

Small defects in the humerus need not be supported by any type of external fixation A bandage applied firmly over the wound together with a sling, affords sufficient protection to the extremity In fact, early mobilization of the shoulder joint should be encouraged This prevents the formation of adhesions between the soft tissue strata and contracture of the adductor muscles

In the event of a pathologic fracture prior to curettage or a large defect with the cortical shell so thin that bone fracture is inevitable if unprotected following curettage the part should be protected until new bone formation obliterates the defect The best method of external fixation is a shoulder spica made of plaster-of paris applied immediately after operation.

Resection. This procedure is indicated only rarely for giant-cell tumors in the upper end of the humerus because of the subsequent impairment of shoulder joint *function* Resection is justifiable in this region only if there is recurrence of the tumor after curettage. Some shoulder joint function may be restored following resection of the upper end of the humerus by replacing the resected bone with the proximal end of *the fibula (Fig 357, top right* and *bottom)*

Amputation. Better understanding of the nature and the cause of giant-cell tumors condemns amputation of the upper extremity as primary treatment of these lesions. Amputation is indicated only when there is clinical and histologic evidence that the neoplasm has undergone malignant transformation (for technic see Chap 11) following treatment by irradiation or surgery Occasionally such undesirable sequelae as infection and irradiation necrosis may render the extremity useless here amputation is advisable Primary amputation is performed however, only when histologic study reveals frankly the existence of a malignant giant-cell tumor

Prognosis

Many factors must be evaluated when considering the prognosis of giant-cell tumors Notably are the age of the patient the site of the tumor and characteristics of the stromal cells In general the outlook is better in young individuals and lesions in the upper extremity give a more favorable prognosis than those in the lower extremity (Coley) The work of Jaffe on aggressiveness of giant-cell tumors based on changes in their stromal cells provides some aid in prognosticating the clinical behavior of a given tumor

Finally the prognosis is unfavorable in lesions which tend to recur following treatment Such behavior should arouse suspicion of malignant transformation and should influence the prognosis accordingly

Preoperative and Postoperative Radiation

There is general agreement that preoperative irradiation is not desirable mild dosage has little effect on the course of the tumor and heavy radiation may delay or inhibit new bone formation Postoperative radiation may be harmful for the same reasons and is needless therapy if thorough curettage has been performed

EPIPHYSEAL CHONDROMATOUS GIANT CELL TUMOR (CODMAN) [BENIGN CHONDROBLASTOMA OF BONE (JAFFE)]

INTRODUCTION

In 1931 Codman reported nine cases of this tumor which he found in the *Sarcoma Registry*. They paraded under such erroneous diagnoses as osteogenic sarcoma, chondrosarcoma and giant-cell tumors. He believed these tumors were found only in the region of the humeral head and that they were atypical giant-cell tumors. He wrote, "It is my belief that the peculiar structure of the head of the humerus makes the picture of giant-cell tumor so modified that typical cases do not often occur."

Since the first description of these lesions, they have been observed in the epiphyseal regions of other long bones (lower end of the femur and upper and lower ends of the tibia).

ORIGIN

Investigators differ as to the origin of epiphyseal chondromatous giant-cell tumors. Codman was of the opinion that this type of neoplasm was a benign giant-cell tumor arising in the region of the tuberosities of the head of the humerus at an age before complete ossification of the epiphyseal cartilages, that the peculiar epitheloid cells which merge into a low grade type of cartilage cell found in the tumor arose from the epiphyseal cartilage. Willis reports a case whose histologic structure supports the views of Codman.

On the other hand, Geschickter describes this lesion under the title of "chondroblastic tumors, benign and malignant," believing that these lesions arise from the metaphyseal side of the epiphyseal line and that "the proliferating tissue was chondroblastic rather than composed of giant cells." Coley states that he knows of no verified instance of metastasis of this tumor and that in all the cases under his observation a cure was effected by conservative treatment. Jaffe and Lichtenstein (1942), convinced that the tumors have a cartilaginous origin, named the lesion "benign chondroblastoma of bone." Despite the inconsistencies as to its origin, it is generally conceded that this tumor is a definite entity possessing benign characteristics.

CLINICAL FEATURES

A survey of the cases reported in the literature discloses that the tumor occurs at a period in life when the epiphyseal plates of the upper end of the humerus are still open. Codman's nine cases ranged from 12 to 24 years of age. Males are affected more frequently than females. As previously mentioned, the region of the tuberosities of the upper end of the humerus, primarily the greater tuberosity, is involved most commonly. The onset and the clinical course are mild.

In Codman's series the duration of the disease before treatment varied from 5 to 36 months. Trauma as an etiologic factor has not been proved, although it may make the patient cognizant of an existing lesion. Pain and restriction of shoulder motion are the cardinal symptoms. Later swelling of the upper end of the humerus may be demonstrable; also tenderness over the greater tuberosities may be elicited by firm pressure over this region. The benign nature of the neoplasm is evidenced by the fact that conservative measures result in a permanent cure.

ROENTGENOGRAPHIC FEATURES

Benign chondroblastomas usually occupy an eccentric position in the greater tuberosity. No reported tumor ever has extended beyond the proximal epiphyseal line to reach the articular cartilage of the head of the humerus, except in one case reported by Jaffe. These tumors present a "fluffy cotton wool look," are relatively small and are sharply demarcated from the surrounding normal bone by an area of increased density. Irregular areas of calcification scattered through the tumor may give it a mul

Fig 300 Chondroblastoma of the humerus in a male aged 23 Observe the mottled appearance resulting from irregular areas of calcification within the cartilaginous tumor Also observe the pronounced increase in cortical bone in the shaft of the humerus immediately below the tumor a characteristic feature of this tumor

tilocular, flocculent appearance Trabeculations such as seen in giant-cell tumors are absent Unlike giant-cell tumors, new bone is formed on the outer surface of the cortex of the shaft immediately below the tumor This periosteal response is more evident in the older lesions (Fig 300)

Microscopic Features

Histologic study reveals that benign chondroblastoma consists essentially of masses of immature cartilage cells embedded in a cartilaginous matrix Occasionally, areas of calcification and ossification are found in the matrix Varying numbers of giant cells are scattered throughout the tumor

Diagnosis

As previously noted this lesion has often been mistaken for osteogenic sarcoma, chondroblastic sarcoma and chondrosarcoma The location of the tumor its benign course and long duration of symptoms together with its histologic features distinguish it from the aforementioned neoplasms.

Treatment

Radical surgical procedures never are indicated in these lesions The treatment of

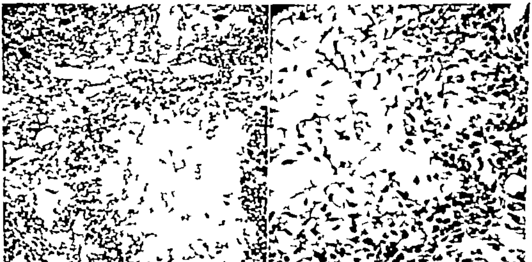

Fig 301 Benign chondroblastoma. The tumor tissue comprises stellate cells in a myxomatous stroma fibroblastic proliferation and numerous chondroblasts. (Photomicrographs × 125 and × 250)

choice is careful curettage of the affected area or excision of the mass where possible Surgical intervention is preferred to irradiation

Prognosis

All the cases of Codman Jaffe and Coley have responded to conservative treatment Benign chondroblastomas do not tend to recur after adequate conservative treatment As to eradication of the tumor and restoration of function at the shoulder joint the prognosis is generally excellent

SOLITARY BONE CYST

Introduction

Solitary bone cyst is a benign neoplasm whose clinical roentgenographic and histologic characteristics have established it as a definite entity It has a predilection for the ends of long bones, its most prevalent sites being the upper ends of the humerus and the femur The close similarity of this lesion to giant-cell tumor has been the source of much controversy relative to its origin

Three distinct varieties of this lesion are recognized (1) The most common form is the bone cyst found in young children in the metaphysis of long bones (on the diaphyseal side of the epiphyseal plate) (2) The latent bone cyst observed in older children and adults is located in the shaft of the bone at some distance from the epiphyseal line (an older form of first variety which during the period of bone growth has migrated toward the middle of the shaft) (3) That group encountered during adolescence border on the epiphyseal disk and display more acute clinical manifestations than do the other two varieties. Histologically they bear close resemblance to giant-cell tumors Coley refers to this classification as an intermediate form between a simple bone cyst and a giant-cell tumor whereas Geschickter considers it as a giant-cell variant of bone cyst (Fig 302)

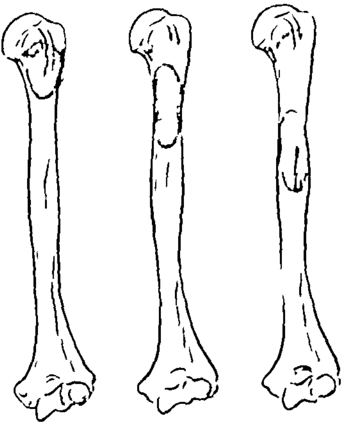

Fig 302 Forms of bone cysts. (A) intermediate form between bone cyst and giant cell tumor found during adolescence (B) bone cyst appearing in childhood (C) latent bone cyst encountered in older children and adults.

Origin

Since Virchow's first description of this lesion in 1878 numerous confusing and contradictory concepts of origin have been postulated each one lacks incontestable evidence for acceptance

Some investigators maintain that these lesions result from metabolic disturbance (Sisk) a theory not substantiated by other workers yet other investigators have proposed that the disease results from intramedullary inflammation (Bloodgood Pfeiffer)—however, bacteriologic investigation has failed to provide conclusive evidence to support this theory Trauma and hemorrhage have aroused the interest of many workers who have attempted to correlate these factors with formation of bone cysts (Mauclaire and Burnier Pommer, Enckel and Mikulicz)

Fig 303 Bone cyst in the upper end of the humerus of a female aged 13 Note the expansile nature of the lesion the thin cortex and the juxta-epiphyseal location No roentgenographic evidence of repair exists.

Geschickter and Copeland maintain that the contents of bone cysts (osteitis fibrosa) are closely related to giant-cell tumors and represent a reparative process of bony elements taking place around an area of bone destruction which soon becomes arrested although the healing or reparative phase may persist for many years giving rise to the latent bone cyst. Failure to collapse the bony walls of the cyst is responsible for persistence of the lesion into adult life This fact is substantiated by the knowledge that fracture of the cortical shell, spontaneous or surgical usually is followed by rapid healing complete obliteration of the cyst may occur

Age, Incidence and Site

Bone cysts are encountered between the ages of 5 and 15 years, the intermediate variety (Coley) or giant-cell variant (Geschickter and Copeland) during adolescence while the latent inactive form is observed in older individuals in whom the lesion has a much longer history or has caused no symptoms

Approximately 50 per cent of all cases of bone cysts are located in the upper ends of the humerus and the femur Males are affected more frequently than females. The highest incidence occurs between 6 and 10 years the age ranges from 3.5 to 60 years the average being 16 4 years

A characteristic feature of active bone cysts which distinguishes them from giant cell tumors is their metaphyseal location always on the diaphyseal side of the epiphyseal line The quiescent or latent variety also originates in this area but gradually migrates toward the midshaft as the bone grows

Pathology

Macroscopic study reveals that the contents of different bone cysts varies considerably The duration of the lesion and the age of the patient are partially responsible for this variation Acute bone cysts of short duration possess a thin enveloping bony shell According to Bloodgood s classification a bone cyst may or may not possess a connective-tissue lining the contents of the cyst may comprise a cavity filled with a yellowish fluid or a solid mesh of fibrous tissue (osteitis fibrosa) Occasionally numerous small cavities are encountered (multilocular cysts)

It is Coley s opinion that the neoplasm is initiated by a subcortical hemorrhage followed first by localized bone destruction then granulation tissue containing osteoclasts (giant cells) fibrosis and finally cyst formation Geschickter and Copeland describe the sequence of the process as first the formation of giant-cell areas followed by the appearance of new blood vessels and hemorrhage Absorption of the hemorrhage,

Fig 304 (*Left*) Recent spontaneous fracture through cyst wall of a male aged 14 No clinical indications of the lesion existed prior to fracture (J Edeiken, Mt Sinai Hospital, Philadelphia) (*Right*) Spontaneous fracture through cyst wall of a female aged 13 Observe reparative process initiated by the fracture. Note the periosteal bone formation bridging the fracture line (A Price Jefferson Medical College)

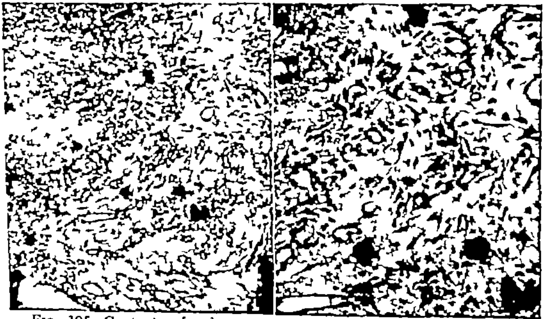

Fig 305 Contents of a bone cyst. Multinucleated giant cells are scattered throughout the tissue which simulates osteitis fibrosa. The tissue abounds in endothelial cells and fibroblasts (Photomicrographs × 125 and × 250)

in turn results in the formation of cysts lined with connective tissue which ultimately is transformed into bone (Fig 303)

Generally progression of bone cysts is slow its rate of growth is in accordance with the severity of the symptoms The affected bone portion slowly expands as the overlying cortex becomes very thin. No evidence of bone reaction is discernible in the more acute types although some condensation of the bony shell is demonstrable in the latent forms Fracture may ensue following minor trauma to the weakened bone Fracture stimulates healing as evidenced by rapid new bone formation In some instances, the healing following fracture may obliterate the cyst

Microscopic study discloses wide variation in the histologic structure of bone cysts Some cases bear a close resemblance to giant-cell tumors this is particularly true of the intermediate varieties observed during adolescence Other cysts do not differ from osteitis fibrosa It is apparent that the variations mentioned are different stages of the same pathologic process and are related to giant-cell tumors Many investigators maintain that the variable factors responsible for the different behaviors of bone cysts and giant-cell tumors include the age of the patient the region of the bone affected and the response of the surrounding bone to the pathologic process In the metaphysis sufficient resistance is encountered to limit the aggressiveness of the lesion while in the epiphyseal region less resistance is offered by the cancellous bone thereby allowing the destructive phase to progress Hence, in the metaphysis the process results in bone cysts while giant-cell tumors result in the epiphyseal region

Clinical Features

Not infrequently bone cysts are discovered accidentally through roentgenograms taken for reasons not related to the affected region The first indication of a bone cyst in children may be a pathologic fracture following minor trauma. In general any symptoms present are mild, varying in duration from a few months to many years Bone cysts found in adolescence run a more acute clinical course, the duration being under 6 months Latent cyst may date back from 20 to 40 years, with an average duration period of 2½ years.

Pain Pain is seldom a prominent clinical feature. It may occur only after exertion and may be relieved by rest Of course, the symptom is accentuated when fracture occurs Pain is usually in the region of the upper end of the humerus, occasionally, it is referred posteriorly to the scapular region Firm pressure over the affected bone invariably elicits moderate tenderness

Swelling This sign is rarely detectable because of the fleshy deltoid muscle covering the upper end of the humerus. Palpation of the area, particularly in more progressive lesions, reveals a fusiform enlargement of the upper end of the humerus as compared with the opposite side.

Impaired Function. Function of the shoulder joint is seldom impaired However it is obvious that disability is increased when fractures occur

Roentgenologic Features

The distinctive features of bone cysts are (1) a destructive lesion in the metaphysis in growing individuals (before closure of the epiphyseal line) (2) uniform expansion of the metaphyseal region of the shaft, (3) a smooth thin cortical shell and (4) the occasional occurrence of irregular trabeculae throughout the bone defect.

These features may be absent in acute early lesions The lesion on the radiographs may appear as a radiolucent area in the metaphysis close to the epiphyseal disk. Lack of bone reaction is a characteristic finding in all uncomplicated bone cysts. Radiographic evidence of new bone formation is readily discernible in case of fractures. Also as previously noted some bone condensation is demonstrable around a latent cyst.

Diagnosis

The age of the individual, the location of the lesion in the metaphysis (on the diaphyseal side of the epiphyseal plate) roentgenologic characteristics and a mild clinical course are sufficient to establish a diagnosis of bone cyst Lesions which occasionally require consideration in diagnosing this neoplasm are giant-cell tumor, benign chondroblastoma and chondroma

Giant-cell tumors occur in older individuals (after 20 years of age) when the upper epiphysis has united to the shaft of the humerus They are located in the epiphysis, starting from an eccentric position and extending centrally and toward the articular cartilage

Benign chondroblastomas usually are confined to the region of the greater tuberosity they do not cross the proximal or distal epiphyseal plates they have a fluffy, mottled appearance and histologic studies reveal that they consist essentially of immature cartilage

Chondromas may bear a close resemblance to bone cysts however they are rarely found in long bones

Treatment

There is general agreement that surgical intervention is the treatment of choice Implantation of bone chips or longer segments of bone parallel with the long axis of the cyst ensures more rapid regeneration of bone and minimizes the possibilities of spontaneous fracture through the affected area. Although pathologic fractures initiate healing which occasionally obliterates the bone cyst curettage of the cavity and reinforcement with bone chips assures more prompt healing The surgical technic employed in the treatment of these lesions is similar to that of giant-cell tumors (see pp 333)

Irradiation of bone cysts is not warranted because it may damage the epiphysis or even result in premature ossification of the epiphyseal disk thereby interfering with normal bone growth which in turn may result in the shortening of the humeru Also the possible development of sarcoma in irradiated bone is a definite contraindication to the use of roentgen rays in cases where other forms of therapy are more effective

Recurrences of the bone cyst subsequent to curettage is not a frequent occurrence A second curettage or in rare instances even a third may be necessary to achieve a cure

SARCOMAS OF THE BONE

Incidence and Age

In 1922, Codman made a survey of bone sarcoma in Massachusetts and estimated an incidence of one case in every 100 000 inhabitants at any one time According to Coley, there is an incidence of one case of osteogenic sarcoma for every 117 000 of the population in the United States Sarcoma of bone is a little more prevalent in males than in females

As previously stated, half of all cases occur in the second decade and two-thirds occur between the ages of 10 and 30 years In patients over 50 years of age osteogenic sarcoma usually indicates the existence of Paget's disease of bone with sarcomatous degeneration

Site

Over a tenth of all bone sarcomas are found in the bones of the shoulder girdle (Codman records 13 5 per cent), the humerus being the most frequent location The clavicle is rarely affected As in all tubular bones the preferred site in the humerus is in the metaphyseal region

Gradation of Degree of Malignancy

Some investigators believe that it is possible to determine the degree of malignancy of sarcomas of bone by the histologic characteristics of the cells and the tissues comprising the neoplasm Broder has evolved a classification of gradation based on the differentiation of cells Some workers hesitate to place too much faith on such a gradation while others rely heavily on the

pathologist s classification before institut ing definitive therapy for a specific lesion

Meyerding is convinced that the grading of malignant tumors has reached a high degree of proficiency at the Mayo Clinic. The decision of the pathologist therefore, plays a major role in the choice of treat ment or the extent of surgery performed He states

When after thorough study of the sections of tissue the pathologist reports a Grade I osteogenic sarcoma, I feel that there may be some merit in performing a more conservative type of operation whereas when he reports a Grade 4 or higher degree malignant lesion I would without hesitation perform amputa tion of the involved extremity In some cases it is possible to excise in toto the portion of bone containing the tumor and insert a bone graft without the danger of local recurrences or metastasis.

The value of grading as an aid in prog nosticating the course of neoplasms is apparent Coley notes that the percentage of 5 year survivals in low grade tumors is more than twice that of the higher grades com bined However he does not believe that fine subdivisions of grading into numerous groups is of any practical significance

OSTEOGENIC SARCOMA

Essentially this group comprises tumors originating in bone and capable of produc ing bone It makes up over 50 per cent of all bone sarcomas The character and the amount of bone produced varies in different tumors giving rise to several clinical types Generally the outlook is unfavorable and the mortality is high In the humerus as in other long bones the tumors originate in the metaphysis and tend to grow outward under the deltoid and downward into the shaft of the humerus As a rule they do not invade the head of the humerus or break through into the capulohumeral joint In vasion of the medullary canal and destruc tion of the cancellous and cortical bone is a characteristic feature of these neoplasms

Stimulation of the periosteum by the ad vancing tumor may lead to varying amounts of new bone formation in the shaft distal to the tumor (Codman s triangle) With dissolution and perforation of the cortex the tumor mass may progress beyond the limits of the bone varying degrees of ossification may occur in the tumor outside the shaft. Early metastasis to the lungs is the rule, generally, dissemination of the tumor is achieved via the blood stream, but occasionally by the lymphatic.

Pathologic fracture of the humerus is not infrequent Of 24 cases of osteogenic sar coma of the upper end of the humerus re viewed by Codman (1930), 19 exhibited fractures through the involved area of the humerus Coley and Sharp (1930) observed that pathologic fracture was more common in the humerus than in the femur despite the fact that the latter is a weight bearing bone (Four of the five cases which had not sustained a fracture were classified as sclerosing osteogenic sarcomas)

SCLEROSING OSTEOGENIC SARCOMA

This form is observed most commonly in the lower extremity Although it is encoun tered not infrequently in the upper end of the humerus it is rarely observed in the scapula and the clavicle Ages ranged from 8 to 61 years the average being 19.3 years. Males were affected more frequently than females The highest incidence is found be tween 11 and 15 years

In the humerus as in other long bones the tumor arises in the metaphyseal region. Its clinical course is not so acute as the osteolytic form the duration of symptoms from onset to treatment being less than a year (In contrast with other varieties of osteogenic sarcoma, pathologic fracture is rare)

Palpation in advanced cases reveals an irregular hard bony tumor in the upper end of the humerus. The deltoid may partly conceal the bony mass invariably how ever the deltoid region appears fuller and more prominent than the unaffected side The cases observed by the author exhibited some impairment of shoulder function As a

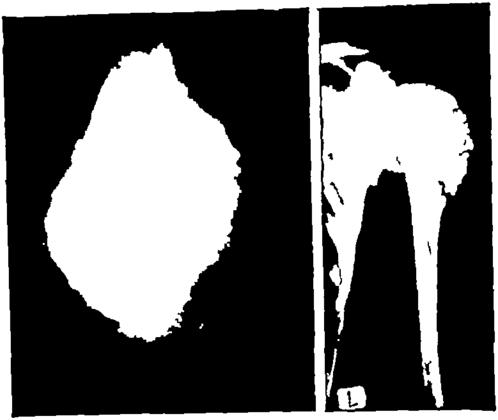

FIG 306 Sclerosing osteogenic sarcoma of humerus (*left*) Patient developed this primary lesion after a similar primary lesion had developed in the femur (*right*) which was treated by amputation (Coley Neoplasms of Bone, New York Hoeber p 239)

rule motion was guarded, and movements of the arm were kept below the horizontal even though the disability was not severe

The roentgenographic features of this tumor are characteristic. Irregular areas of increased density obliterating the pattern of normal bone appear in the metaphyseal region of the humerus As the tumor grows the cortex is destroyed and the soft tissues are invaded the same dense areas of tumor bone appearing beyond the confines of the shaft of the humerus The tumor rarely crosses the epiphyseal line to involve the humeral head Fine spicules of tumor bone radiating at right angles to the shaft of the humerus may be seen giving the "sun ray" appearance, believed by many to be a pathognomonic feature of malignant bone sarcoma However this peculiar "sun ray" occurs in other affections of bone (Fig 306)

FIG 307 Osteolytic form of osteogenic sarcoma involving the entire upper end of the humerus. Note complete dissolution of bony elements and extension of tumor tissue into the surrounding soft tissues. (Geschickter and Copeland Tumors of Bone ed. 3 Philadelphia Lippincott, p 217)

TELANGIECTATIC SARCOMA OF THE BONE (OSTEOLYTIC TYPE OF OSTEOGENIC SARCOMA OR MALIGNANT BONE ANEURYSM)

This tumor is relatively rare and its origin is not definitely established Diagnosis may be exceedingly difficult, this tumor

FIG 306. Rare type of osteogenic sarcoma (medullary fibrosarcoma) of the upper end of the humerus. Note the irregular destruction of the cancellous bone extending distally in the medullary canal the head of the humerus is spared. In this instance there is no radiographic evidence of periosteal bone formation.

often being confused with bone cysts giant cell tumors and metastatic carcinoma. It is a highly destructive vascular lesion, very malignant, and carries an unfavorable outlook. Telangiectatic bone sarcomas are encountered more frequently in the second decade of life but may occur in older age groups Pathologic fracture is a common sequela some series report an incidence of approximately 50 per cent. Ages range from 13 to 60 years the average being 28 5 years The highest incidence occurs between 16 and 20 years.

The shoulder region exhibits a fusiform or globular swelling of the proximal end of the arm the skin may be stretched tightly over the tumor but it may remain freely movable the surface temperature of the affected area may be increased. The tumefaction may be soft and boggy Shoulder function is usually impaired somewhat.

Roentgenologic studies reveal pronounced destruction as if the bony elements of the upper end of the humerus were melting away The articular head is usually spared, and the tumor does not invade the joint cavity However in advanced cases the head of the humerus and the joint cavity may be implicated Early cases may show new periosteal bone formation on the shaft distal to the tumor and even sun ray spicules. Later, with tumor progression, no evidence of new bone formation may be discernible. Pathologic fracture as noted above is a frequent sequela (Fig 307)

MEDULLARY AND SUBPERIOSTEAL OSTEOGENIC SARCOMA

This subdivision comprises a relatively common group of osteogenic sarcomas which originate within the bone destroy first the spongiosa and then the cortex. Tumor tissue grows and extends into the medullary canal and occupies a position under the raised periosteum.

Tumor bone forms varying in amount and degrees of differentiation. Reactive new bone formation is laid down by the periosteum distal to the tumor in an attempt to obstruct its progression. As the tumor grows, reactive bone is destroyed and nature lays down another layer distal to the limits of the tumor Again, as in other types, the humeral head is not invaded the tumor does not extend beyond the epiphyseal line.

FIBROSARCOMA OF BONE

It is now generally conceded that fibrosarcoma may arise from the fibrous connective tissue or from the tissue forming the outer layers of the periosteum. The neoplasms never form bone they consist chiefly of spindle cells whose degree of malignancy depends upon the degree of cell differentiation. In general they are considered the

FIG 309 (*Top left*) Fibrosarcoma (periosteal sarcoma) in right shoulder of a male adolescent Note that the *shaft of the humerus appears not to be* implicated also the lack of *any new bone formation* (B P Widmann and J C Howell Philadelphia General Hospital) (*Top right*) Later stage of same tumor the shaft of the humerus is still intact showing only minimal alterations (Widmann and Howell) (*Bottom left*) Final stage exhibits complete destruction of the upper end of the humerus. Observe the absence of new bone in the tumor mass. Other similar lesions developed in opposite shoulder (bottom right) and in both femurs This was believed to be an instance of multiple primary sarcomas. (Widmann and Howell.) (*Bottom right*) Left shoulder of patient exhibited in the other figures. Note the extensive tumor without apparent *involvement of the shaft of the humerus.*

least malignant of the osteogenic sarcomas and offer the most favorable prognosis

Medullary fibrosarcomas originate in the cancellous bone near the epiphyseal line The tumor invades the spongiosa eroding and perforating the cortex. The elevated periosteum may lay down reactive bone around and distal to the tumor Radiographically there is no evidence of tumor bone formation hence the central area of destruction in the end of the shaft is depicted as an irregular radiolucent area sometimes confused with the more malig nant osteolytic sarcoma or with a central chondroma (Fig 308)

Fibrosarcoma originating from the outer layers of the periosteum does not form bone and it exhibits little tendency to invade the adjacent bone However sometimes the bone is involved thus making it difficult or impossible to determine the origin of the neoplasm (Fig 309) Fibrosarcomas are amenable to surgery and it is agreed that if they were treated early the survival rate of this group would be increased greatly Unfortunately in most instances treatment is initiated only after metastasis

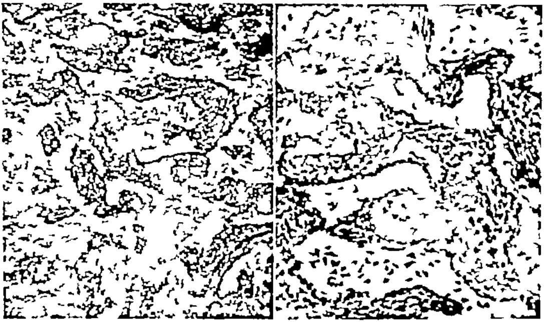

FIG 310 Osteogenic sarcoma (osteoblastic form) (× 125 and × 250) Observe the formation of irregular osteoid trabeculae whose peripheries are lined by numerous malignant osteoblasts. Also note that the osteoid tissue lacks a definite pattern it is laid down in a disorderly fashion numerous vascular channels are dispersed throughout the tissue.

EWING'S SARCOMA

INTRODUCTION

Ewing's tumor is now accepted as a defi nite entity with characteristic clinical, radiographic and histologic features However there is much controversy as to its histogenesis. Ewing described the neoplasm as consisting of angio-endothelial cells and believed it to be of endothelial origin. Jaffe and Lichtenstein are of the opinion that it is derived from primitive marrow-connec tive tissue Stout believes that the tumor is a variant of reticulum sarcoma originating from the supporting mesenchymal tissue of the bone marrow while Oberling states that the tumor is a reticulosarcoma

In spite of its obscure and undetermined origin many distinctive features of this bone neoplasm have been uncovered It is exceedingly radiosensitive metastasizes to lung lymph nodes and other bones and usually terminates fatally

INCIDENCE AGE SEX AND SITE

This primary malignant bone tumor is relatively common and occurs most fre-

quently in children and young adults It is rarely encountered after 30 years of age The bones of the shoulder girdle are frequently involved and although it is usually observed in the shafts of long bones it not

Fig 311 Ewing sarcoma involving upper one-half of the humerus in a male 11 years of age Observe the reactive periosteal new bone formation giving the shaft a laminated appearance and the increased density within the shaft indicative of new endosteal bone formation. Radiating spicules of new bone are also discernible. The epiphysis is not implicated. (Geschickter and Copeland Tumors of Bone, ed. 3, Philadelphia Lippincott 1949, p 416)

infrequently arises in the upper end of the humerus Males are affected more frequently than females the ratio being approximately 2 to 1 The age ranges from 4 5 to 44 years the highest incidence being between 6 and 15 years.

Clinical Features

Pain with or without trauma is usually the first manifestation of the disease, and its onset is insidious in most instances It is not severe at first and it may be intermittent in nature Later the pain is constant being most severe at night Swelling is always found being readily demonstrable in the bones of the shoulder joint Marked impairment of function seldom occurs even

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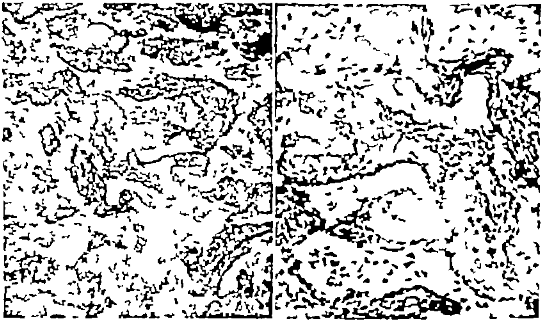

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INTRODUCTION

Ewings tumor is now accepted as a definite entity, with characteristic clinical *radiographic and histologic features* However there is much controversy as to its histogenesis Ewing described the neoplasm as consisting of angio-endothelial cells and believed it to be of endothelial origin Jaffe and Lichtenstein are of the opinion that it is derived from primitive marrow-connective tissue Stout believes that the tumor is a variant of reticulum sarcoma originating from the supporting mesenchymal tissue of the bone marrow while Oberling states that the tumor is a reticulosarcoma

In spite of its obscure and undetermined origin many distinctive features of this bone neoplasm have been uncovered It is exceedingly radiosensitive metastasizes to lung lymph nodes and other bones and usually terminates fatally

INCIDENCE AGE SEX AND SITE

This primary malignant bone tumor is relatively common and occurs most fre

quently in children and young adults It is rarely encountered after 30 years of age The bones of the shoulder girdle are frequently involved and although it is usually observed in the shafts of long bones it not

FIG 311 Ewing sarcoma involving upper one-half of the humerus in a male 11 years of age Observe the reactive periosteal new bone formation giving the shaft a laminated appearance and the increased density within the shaft indicative of new endosteal bone formation Radiating spicules of new bone are also discernible The epiphysis is not implicated (Geschickter and Copeland Tumors of Bone, ed. 3, Philadelphia Lippincott 1949, p 416)

infrequently arises in the upper end of the humerus Males are affected more frequently than females the ratio being approximately 2 to 1 The age ranges from 4 5 to 44 years, the highest incidence being between 6 and 15 years.

CLINICAL FEATURES

Pain with or without trauma is usually the first manifestation of the disease and its onset is insidious in most instances It is not severe at first and it may be intermittent in nature Later the pain is constant being most severe at night Swelling is always found being readily demonstrable in the bones of the shoulder joint Marked impairment of function seldom occurs even

least malignant of the osteogenic sarcomas and offer the most favorable prognosis

Medullary fibrosarcomas originate in the cancellous bone near the epiphyseal line The tumor invades the spongiosa, eroding and perforating the cortex. The elevated periosteum may lay down reactive bone around and distal to the tumor Radiographically there is no evidence of tumor bone formation hence the central area of destruction in the end of the shaft is depicted as an irregular radiolucent area sometimes confused with the more malignant osteolytic sarcoma or with a central chondroma (Fig 308)

Fibrosarcoma originating from the outer layers of the periosteum does not form bone and it exhibits little tendency to invade the adjacent bone However sometimes the bone is involved thus making it difficult or impossible to determine the origin of the neoplasm (Fig 309) Fibrosarcomas are amenable to surgery and it is agreed that if they were treated early, the survival rate of this group would be increased greatly Unfortunately in most instances treatment is initiated only after metastasis

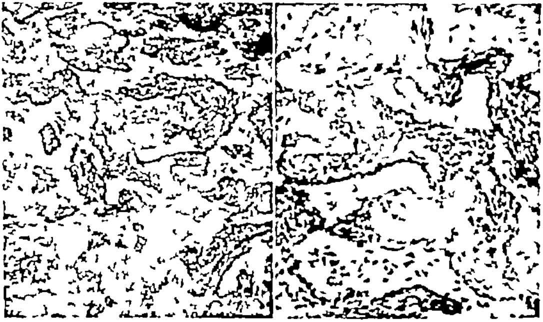

FIG 310 Osteogenic sarcoma (osteoblastic form) (× 125 and × 250) Observe the formation of irregular osteoid trabeculae whose peripheries are lined by numerous malignant osteoblasts. Also note that the osteoid tissue lacks a definite pattern it is laid down in a disorderly fashion numerous vascular channels are dispersed throughout the tissue

EWING'S SARCOMA

INTRODUCTION

Ewing's tumor is now accepted as a definite entity, with characteristic clinical, radiographic and histologic features However there is much controversy as to its histogenesis Ewing described the neoplasm as consisting of angio-endothelial cells and believed it to be of endothelial origin Jaffe and Lichtenstein are of the opinion that it is derived from primitive marrow-connective tissue Stout believes that the tumor is a variant of reticulum sarcoma originating from the supporting mesenchymal tissue of the bone marrow while Oberling states that the tumor is a reticulosarcoma

In spite of its obscure and undetermined origin many distinctive features of this bone neoplasm have been uncovered It is exceedingly radiosensitive metastasizes to lung lymph nodes and other bones and usually terminates fatally

INCIDENCE AGE SEX AND SITE

This primary malignant bone tumor is relatively common and occurs most fre-

they are very poor Resection holds no more hope for the patient but he is spared a mutilating operation Moderate doses of roentgen therapy before amputation or resection and heavier dosages after the wound has healed is the plan of treatment in most institutions.

Prognosis on the whole is poor metastases and death are the usual sequelae The survival period after the initial symptoms of the disease appear varies but it is rarely more than two years

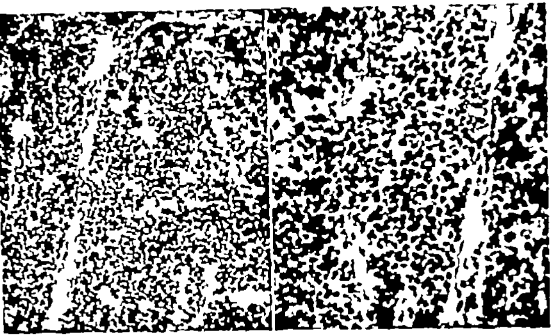

FIG 312 Ewing s sarcoma. Observe the compact areas of small polyhedral cells with a hyperchromatic nucleus and scanty cytoplasm No intercellular stroma is present. (Photomicrographs × 125 and × 250)

OSTEOID OSTEOMA

INTRODUCTION

Osteoid osteoma is now generally accepted as a distinct clinical entity It has been encountered in all the bones of the body except the cranial bones the scapula and the clavicle Most investigators agree with Jaffe that it is a benign *neoplasm* of bone However a few refuse to accept this concept believing that the *lesion* is a chronic bone infection or abscess (Brown and Ghormley Brailsford) The weight of evidence is against the infectious theory Lack of such systemic reactions as leukocytosis and consistent negative bacteriologic and histologic studies tend to discredit the infectious theory Trauma plays no part in the histogenesis of the tumor It is often confused with Brodie s abscess and Garre s sclerosing osteitis

AGE, SEX AND INCIDENCE

The neoplasm is more prevalent in males than in females It has a predilection for adolescents and young adults, although Sherman reports one instance in an individual 51 years old The highest incidence is found between the ages of 10 and 20 years

SITE

Sherman reported 158 cases of osteoid osteoma 128 of which were gathered from the literature The lesion was found in all bones of the skeletal system except the cranial bones the scapula and the clavicle Ten of the cases (6.2 per cent) were encountered in the humerus The most frequent site is the tibia and the femur It may be observed in the cancellous bone near or

with extensive involvement. Pathologic fracture is more frequent in the upper end of the humerus than elsewhere

Constitutional reactions such as fever and leukocytosis are common manifestations of the disease responsible, in many cases, for the erroneous diagnosis of osteomyelitis Not infrequently such cases have been operated upon and the diagnosis has not been established until after meddlesome surgery had been performed

The disease tends to pursue a variable clinical course and is usually fatal Metastases may take place early in the lungs and the lymph nodes, later in other bones and viscera the bones of the skull are frequent sites for metastatic lesions Reported cases reveal that the time range between the first appearance of bone lesion and multiple bone involvement ranges from 2 5 months to 4 years

Ewing s sarcoma is osteolytic in nature and never produces bone the new bone formation noted radiographically is reactive bone formed by the periosteum and endosteal elements through stimulation by the advancing tumor In the early stages increased density and expansion of the shaft of humerus may be discernible this results from endosteal and subperiosteal bone formation Subperiosteal bone is laid down parallel with the shaft giving the onion peel effect often described as characteristic of Ewing s tumor

Later the tumor extends along the shaft of the humerus with destruction of the cortex irregular mottling and osteoporosis of the medullary cavity and increased density of the tumor s periphery resulting from periosteal bone formation Reactive bone formation is usually more abundant in children than in adults In advanced lesions dense spicules of necrotic bone may be demonstrable simulating an infectious process of bone (Fig 311)

Pathology

The tumor arises in the medullary canal it destroys and infiltrates cancellous bone and then cortical bone It extends up and down the medullary canal the shaft expanding as it grows With destruction of the cortex, the tumor proliferates beneath the periosteum large amounts of tumor tissue are found in this position in advanced cases. Marked thickening of the shaft may result from endosteal and subperiosteal bone formation Only rarely does the tumor cross the epiphyseal line Subperiosteal bone is laid down parallel with the shaft but, with separation of the periosteum new bone is formed at right angles to the shaft following the course of the blood vessels (Ribbert)

Histologic study reveals that the tumor consists of compact areas of small polyhedral cells with a round hyperchromatic nucleus and scanty cytoplasm with distinct but slightly irregular outline No intercellular stroma is present Microscopic interpretation of this lesion is most often confused with reticulum-cell sarcoma and metastatic bone lesions from neuroblastoma of the sympathetic system Willis is of the opinion that frequently the latter is diagnosed erroneously as Ewing s tumor (Fig 312)

Prognosis and Treatment

Ewing s tumors are very radiosensitive, but irradiation alone never has effected a cure Roentgen ray therapy relieves pain and causes regression of the primary tumor However it does not prevent metastasis, which invariably follows regardless of the local status of the initial neoplasm Inadequate dosages of irradiation tend to make the tumor less radiosensitive

Surgical intervention with or without irradiation is accepted as the best form of therapy Coley states that resections should be performed more frequently in such bones as the fibula the ulna and even the scapula and the humerus He justifies this opinion by the fact that amputation offers no more hope of cure than does resection.

Statistics reveal that the results of amputation are far from encouraging in fact

of the entire circumference of the shaft Early cases may fail to reveal any radiographic findings, however, subsequent examinations will uncover the true nature of the disease

Pathology

Gross study of the nidus reveals it to be a small cavity usually under 2 centimeters in diameter and containing friable, reddish brown substance Microscopic examination discloses a highly vascular connective tissue stroma in which are found trabeculae of osteoid tissue some of which is irregularly calcified to form osseous tissue Multinucleated giant cells may be present (Fig 313)

Treatment

The most effective form of therapy now known is block resection of the nidus and a portion of the surrounding bone If the lesion is completely removed pain disappears immediately and recurrence of the symptoms does not occur This is not true if the nidus and its contents are not totally removed as occasionally occurs following curettage or inadequate block resection The train of symptoms is not interrupted with incomplete removal Even upon awakening from the anesthesia the patient will continue to complain of the same type of pain If the defect is large in tubular bones (such as the humerus) postoperative immobilization of the extremity should be insisted upon to prevent fracture through the operative site until a sufficient amount of new bone is formed This period may be shortened by filling in the bone defect with bone chips

The author has seen such an unfortunate complication following block resection of an osteoid osteoma in the radius Sufficient data have not been accumulated to predict the outcome of untreated cases Jaffe is of the opinion that spontaneous clinical arrest occurs after many years Sherman records one case under Phemister s observation in which the diagnosis of osteoid osteoma by the present-day criterion was apparent The patient refused surgery pain and tenderness subsided gradually and 7 years later had disappeared completely Radiographic examination 24 years later revealed persistent thickening and sclerosis of the cortex the nidus was not visible The patient was completely free of all symptoms

CHONDROSARCOMA

Introduction

Chondrosarcoma was included in the general classification of osteogenic sarcoma up to 1939 However a realization that these tumors arise from cartilage, the greater portion of or even the entire tumor consisting of cartilage and exhibiting varying degrees of differentiation, plus the knowledge that they pursue a more protracted clinical course than most osteogenic sarcomas forced the Committee of the Registry of Bone Sarcoma to remove these neoplasms from the general classification of osteogenic sarcomas and assign them to the separate division "*chondrosarcoma* They were further subdivided into (1) primary chondroblastic sarcoma and (2) secondary chondrosarcoma.

Primary Chondroblastic Sarcoma

These tumors have a predilection for the ends of the long bones and are encountered most frequently (in order of frequency) in the region of the knee the shoulder and the hip They arise in the cancellous bone from cartilage in the region of the epiphyseal plate Primary chondroblastic sarcomas are exceedingly malignant and do not differ essentially in clinical course and prognosis from osteolytic osteogenic sarcoma

Clinical Features. Like other osteogenic sarcomas primary chondroblastic sarcomas usually occur in the second decade of life the highest incidence being between 10 and 15 years The shoulder region is a frequent site of all primary chondroblastic sarcomas

Pain swelling and impaired function are the cardinal clinical features. Pain may be mild and is often associated with some form

at a distance from the articular cartilage, or it may occupy an intracortical or a subperiosteal position

Clinical Features

Pain is the cardinal clinical manifestation of this disease The author has observed one case of osteoid osteoma in the middle third of the humerus. At first the pain which had existed 8 months before the patient sought medical advice was mild and vague localized in the region of the deltoid tubercle It was relieved by rest and accentuated by activity Later the pain became more constant and was noticed to be centered on the anterolateral aspect of the humerus Nocturnal pain is a common complaint In the instance just mentioned the patient s sleep was often interrupted by excruciating pain Sherman reports several cases in which impaired function occurred in the adjacent joint fluid being also demonstrable within the joint simulating a primary arthritis

The author has observed these findings in two cases involving the distal end of the radius in which the wrist joint was affected and one case involving the proximal phalanx of the index finger In the last instance there was pronounced swelling of the metacarpophalangeal joint However these findings were not noted in the lesion involving the humerus probably because the diseased area was at some distance from the articular surface of the humeral head Reported cases disclose that pain may be present from 2 months to 2 or more years before relief is sought

In those areas in which there is little overlying soft tissue, swelling and thickening of the bone may be palpable Point tenderness over the affected bony area is a constant finding Such local evidence of inflammation as redness increased local temperature and edema of the soft tissues is absent—as are other systemic manifestations of infection such as fever and leukocytosis

Fig 313 Osteoid osteoma. The tissue is rich in fibroblasts and osteoblasts forming osteoid spicules. (Photomicrographs × 32 and × 16)

Roentgenologic Features

Diagnosis is usually made through the distinctive radiographic characteristics In most instances a small round or ovoid radiolucent area surrounded by dense sclerotic bone is discernible The central rarefied area or nidus is sometimes demonstrable only in laminographic examination. However the dense sclerotic bone is always visible the extent of this sclerotic hypertrophied bone varies with the location and the duration of the lesion Lesions of long duration in the cortex or near the periosteum are usually associated with pronounced regional thickening of the shaft while those located in the spongiosa are surrounded by a circumscribed area of bone of varying density which is seldom marked Occasionally intracortical lesions cause thickening

throughout which may be found cystic and hemorrhagic areas Its consistency varies according to the type of cartilage and the amount of calcification and ossification plus the extent of tissue degeneration

Microscopic examination reveals pronounced variation in different tumors, also in different areas of the same tumor The bulk of the tumor comprises cartilage cells exhibiting varying stages of differentiation and calcification a cartilaginous matrix and varying amounts of myxomatous tissue The stage of differentiation of the cartilage tissue indicates the degree of malignancy Neoplasms exhibiting the least differentiation are the most malignant (Figs 315 and 316)

Treatment and Prognosis. Surgery still

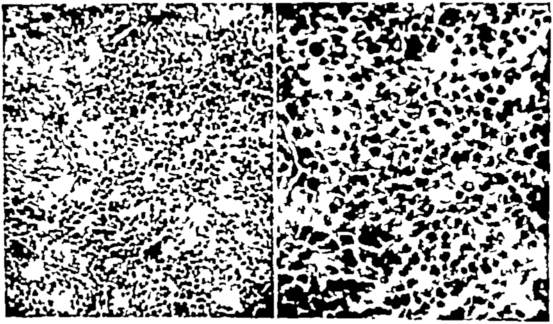

FIG 315 Chondroblastic sarcoma Note the pleomorphic nature of the chondroblasts marked vascularity of the tissue and lack of stroma. (Photomicrographs × 125 and × 250)

FIG 316 Chondrosarcoma Observe cellular pleomorphism numerous double nucleated cells and loss of polarity of the chondroblasts. Although not numerous several cells show mitotic figures (Photomicrographs × 125 and × 250)

of trauma early in the disease The duration of symptoms before examination varies from 7 to 16 months. Pain becomes more constant and function at the shoulder becomes definitely impaired as the lesion progresses Spontaneous fractures rarely occur Like other osteogenic sarcomas, rapidly growing tumors may show such severe bodily reactions as elevated temperature loss of weight and leukocytosis The lesion may assume extraordinary dimensions in the shoulder region The swelling may have a doughy, elastic consistency at first later it may become strong and hard with secondary calcification within the tumor

Metastases to lungs via the blood stream occurs early in the disease No proved cases of metastases by way of the lymphatic system have as yet been recorded

Chondrosarcomas are radioresistant lesions surgery has proved to be the most effective form of therapy As pointed out by Coley the serum phosphatase level in these lesions invariably is elevated and its range is indicative of the activity of the tumor If there are no metastases, the level diminishes following therapy

Roentgenographic Features. Lesions beginning centrally are often depicted as irregular radiolucent areas, resulting from the destruction of the spongiosa and with no evidence of new bone formation or bone condensation around them They involve both sides of the epiphyseal line and extend to the articular surface of the humeral head Such lesions mimic giant-cell tumors osteolytic osteogenic sarcomas and bone cysts. With destruction of the cortex and involvement of the periosteum, an area of dense bone may be seen around the lesion. Also elevation of the periosteum by the tumor may produce bone formation along the shaft distal to the lesion (Codman s triangle) The tumor may be traversed by coarse trabeculae giving it a multilocular appearance

Pathology Macroscopically the tumor consists of a grayish white material

FIG 314 (*Left*) Unusual site for giant cell tumor (male 15 years old) resembling primary chondroblastic sarcoma of upper end of humerus (T N Shallow, Jefferson Medical College.) (*Right*) Material obtained from tumor shown at left. (Photomicrograph × 157)

Roentgenographic Features Roentgenograms may disclose the remains of a chondroma or osteochondroma from which arises an irregular granular blotchy mass Irregular areas of increased density in the tumor are produced by islands of calcification and ossification The tumor may cause extensive destruction of the cortex and invade the medullary canal it may extend peripherally invading the soft tissue Irreg

FIG 317 (*Top left*) Female 53 years old, showing a chondrosarcoma which implicates the left scapula and the upper end of the humerus Biopsy of the tumor was done elsewhere, 6 months after the tumor mass was first noted and the diagnosis of chondrosarcoma was made. The patient was treated erroneously by irradiation (*Top right*) Roentgenograph of the lesion a year after treatment by irradiation (*Bottom left*) Patient 7 days after interthoracoscapular amputation. (*Bottom right*) Photomicrograph (× 150) of tissue obtained from the amputated extremity Observe the pleomorphic character of the chondroblasts and the paucity of stroma.

offers more than any other form of therapy, provided that it is performed early As a rule metastases has already taken place when surgery is instituted Early amputation is the indicated procedure in all cases

The outlook is generally grave Resection of a chondroblastic tumor is rarely justified However it may be done in secondary chondrosarcomas which are shown by histologic studies to be of low grade malignancy and are located in bones which are amenable to resection The prognosis in chondroblastic sarcomas about the shoulder appears to be more favorable than elsewhere in the body

Secondary Chondrosarcoma

Malignant transformation of pre-existing benign cartilaginous lesions such as chondromas and osteochondromas (single or multiple) is not infrequent in bones of the shoulder girdle (Fig 317) This is especially true of benign tumors which involve the scapula and the humerus Secondary chondrosarcoma in patients over 50 years of age may arise in bone affected with Paget s osteitis deformans The highest incidence is found between the ages of 31 and 35 years males are more commonly affected than females. Approximately 20 per cent of all secondary chondrosarcomas occur in areas of the shoulder girdle Although benign chondromas of the coracoid process are rare when present they tend to undergo malignant changes Geschickter informs the author that he has observed 5 malignant transformations occurred in all of them

Characteristic features of significance are the low grade malignant nature of these tumors and the tendency toward repeated recurrences after conservative usually inadequate surgery Occasionally it is not possible to establish the presence of a pre existing cartilaginous tumor by radiographic or histologic studies. However the chronicity of the clinical course pursued may be a clue to the correct diagnosis of secondary chondrosarcoma superimposed on a benign lesion Primary chondrosarcomas exhibit a clinical course that is shorter and more rapid but, in spite of the chronicity and the low grade malignant character of secondary chondrosarcoma most cases end fatally

Clinical Features. Patients with secondary chondrosarcoma usually give a history of a swelling or mild pain in the affected region of the shoulder girdle, present for many months or years before the symptoms developed which forced them to seek medical aid Often the onset was associated with trauma or strain which did not impair function the patient may or may not be aware of a pre-existing mass After many months with or without cause pain swelling and dysfunction appear increasing progressively in intensity

One always should suspect malignant transformation in any pre-existing cartilaginous lesion which is increasing in size and associated with a progressive increase in pain intensity and dysfunction at the shoulder joint Pathologic fracture may occur late in the disease.

Pathology It is often difficult to distinguish these tumors from primary chondrosarcomas. Remnants of the pre-existing tumor may facilitate making the distinction however no such evidence may be demonstrable. The presence of multiple benign skeletal tumors and (in older individuals) evidence of Paget s osteitis deformans in other bones may provide information relative to the origin of the neoplasm

Histologic study discloses that the tumor consists of proliferating connective and varying amounts of myxomatous tissues interspersed with chondral elements Cartilaginous cells in various stages of differentiation and showing mitotic figures indicate the malignant nature of the lesion. Irregular areas of calcification and ossification may be scattered throughout the tumor It may be impossible to distinguish a secondary from a primary chondrosarcoma from microscopic study alone It may also be difficult to distinguish the malignant forms from the benign tumors chondroma and osteochondroma.

Roentgenographic Features Roentgenograms may disclose the remains of a chondroma or osteochondroma from which arises an irregular granular blotchy mass Irregular areas of increased density in the tumor are produced by islands of calcification and ossification The tumor may cause extensive destruction of the cortex and invade the medullary canal it may extend peripherally invading the soft tissue Irreg

FIG 317 (*Top, left*) Female 53 years old showing a chondrosarcoma which implicates the left scapula and the upper end of the humerus. Biopsy of the tumor was done elsewhere 6 months after the tumor mass was first noted, and the diagnosis of chondrosarcoma was made. The patient was treated erroneously by irradiation (*Top right*) Roentgenograph of the lesion a year after treatment by irradiation (*Bottom left*) Patient 7 days after interthoracoscapular amputation (*Bottom right*) Photomicrograph (× 150) of tissue obtained from the amputated extremity Observe the pleomorphic character of the chondroblasts and the paucity of stroma

FIG 318 Chondrosarcoma of humerus in male aged 60 Tumor and upper two-thirds of humerus were resected and fibular transplant performed (J R. Moore.)

ular branching dense shadows giving a stippled blotched appearance are characteristic radiographic features

Treatment and Prognosis. Early radical surgery is the treatment of choice In most instances amputation is justified Secondary chondrosarcoma of the upper end of the humerus and the scapula rarely may be treated successfully by resection Coley reports a case in which a total scapulectomy was done for a chondromyxosarcoma the patient was living 11 years after operation Such conservative measures however are justifiable only in cases which permit total resection of the tumor and the affected bone and which reveal low grade malignancy on careful scrutiny of the histologic structure by a competent pathologist.

Statistics reveal that recurrences invariably follow inadequate surgery The low grade malignancy of some of these tumors is demonstrated by the number of recurrences which occur many years after incomplete removal

The disease pursues a protracted course in these cases. Death may not occur for from 2 to 10 years following recurrences

CHONDROMA

Incidence, Site, Age and Sex

Typical chondromas are central lesions derived from cartilage. They are encountered most frequently in the small bones of the hands and the feet, the ribs and the vertebrae However they also occur in the large bones and in the bones of the shoulder girdle Males are more commonly affected than females, a ratio of slightly more than 2 to 1 The age ranges from 20 to 70 years the peak of incidence in all skeletal chondromas is between 20 and 30 years.

Clinical Features

The only symptom present in the shoulder region may be soreness and mild pain, associated with exertion On the other hand, no disturbing manifestations may be present in quiescent lesions Growing tumors may distend the shaft slowly, causing a uniform swelling of the upper end of the humerus Trivial trauma may produce a fracture Some observers noted a fracture incidence of 10 per cent for all cases of central chondromas. Fracture may be the first sign indicative of the tumor The average duration of symptoms prior to the time when the patient seeks medical advice seems to be 40.5 months.

According to some workers malignant alterations in the tumors occur in 25 per cent of the cases. Aggravation of existing symptoms and the presence of a tumor mass which increases slowly in size is highly suspicious clinical evidence of malignant transformation.

Roentgenographic Features

The significant features of a central chondroma are a radiolucent area fusiform expansion of the shaft of the bone marked

thinning of the cortex complete lack of re active new bone formation and an occasional perforation of the cortex The lesion is extremely rare in long bones such as the humerus but when present it closely resembles bone cyst, giant cell tumor or osteolytic osteogenic sarcoma The diagnosis by clinical and radiographic means is extremely difficult hence histologic examination of the tissue should be made before treatment is instituted Irregular lines of calcification within the tumor occasionally give it a multilocular appearance

Treatment

In the region of the shoulder resection or total excision of the tumor is the treatment of choice If large portions of the shaft are affected segmental resection followed by bone transplantation gives satisfactory results (Fig 357) Large tumors of the scapula may be treated by partial or total scapulectomy lesions of the clavicle are best treated by resection In rare cases resection or excision of the mass may not be possible because of size or location In these instances amputation offers the only hope for the patient particularly if there are indications of malignant changes.

Some workers raise the question as to whether one is justified in such instances even to wait for evidence of malignant transformation believing that these cases are potentially malignant Thus occasionally amputation may be justified before sarcomatous changes manifest themselves.

Small central chondromas may be curetted the cavity cauterized by a saturated solution of zinc chloride followed by thorough irrigation with normal saline solution To enhance new bone formation the cavity may be packed with bone chips or bone grafts

Any surgery performed on chondromas especially of the long bones must be definitive If a biopsy is done complete removal of the tumor by excision or resection should follow The marked tendency for recurrences following surgical procedures makes such precautions imperative Some investigators estimate the incidence of recurrences in large bones to be as high as 25 per cent

In general lesions of such long bones as the humerus should be considered potentially malignant and treated accordingly Lesions in the small bones of the hands and the feet are definitely benign In the latter group extirpation of the lesion invariably produces a cure

OSTEOCHONDROMA

Introduction

This group of benign tumors comprise the most common neoplasms of bone While chondromas are rarely encountered in tubular bones osteochondromas are observed frequently in the ends of long bones Osteochondromas may occur as single or multiple lesions the latter group is recognized clinically as hereditary deforming dyschondroplasia and is associated with skeletal deformities such as bending of the bones shortening resulting from interferences with normal bone growth and widening and distortion of the metaphyseal regions Essentially these tumors all arise from cartilage the amount present being responsible for the clinical and radiographic features

These tumors are generally conceded to be congenital lesions in many instances a familial tendency can be traced through several generations This is especially true of hereditary deforming dyschondroplasia usually observed in the white race Negroes are rarely affected The familial characteristics of such tumors have been emphasized by Ollier Hale Jansen Ehrenfried the Vanzants and many others

Etiology

The true histogenesis of these lesions is still a matter of controversy Although their congenital nature is recognized the exact mode of their development is obscure Geschickter and Copeland state that histogenetically osteochondromas 'are considered to be an exaggeration of a normal bony protuberance intended for the anchor

ing of an important tendon At such a junc ture nature normally provides a protuber ance of bone bulging through a gap in the periosteum to meet an adjoining tendon which co-operates in the formation of the attachment by cartilaginous ossification within the substance of the tendon [1] They state that in multiple exostosis "tags of peri chondrium in the tendon ends proliferate to form cartilaginous and bony outgrowths Disturbances and deficiencies in the peri osteum in the metaphyseal regions lead to widening of the metaphysis and inhibition of bone growth."[2]

Site Incidence Age and Sex

As in other tumors in long bones osteochondromas usually are located at the ends of the humerus not infrequently on the scapula and rarely arise from the clavicle Males are affected more often than females the ratio being 2 to 1 The age range is from 5 to 80 years, the highest incidence occur ring between 11 and 15 years

[1] C F Geschickter and M M Copeland, Tumors of the Bone ed 3 Philadelphia, Lippincott 1949 p. 77

[2] *Ibid.*, p 86

Clinical Features

Many lesions are asymptomatic and are discovered only accidentally by roentgenographic examination of the affected region for reasons unrelated to the neoplasm The patient may or may not be aware of the tumor's presence Occasionally, some form of injury directs his attention to the neoplasm

Quiescent lesions can exist for many years without clinical manifestations some may never give rise to symptoms. Large tumors in the region of the upper end of the humerus may interfere with motion at the shoulder joint In these cases palpation usually discloses a firm painless more-or less symmetric mass attached to the under lying bone The consistency of the mass depends upon the amount of cartilaginous tissue Soft tissues are freely movable over the mass

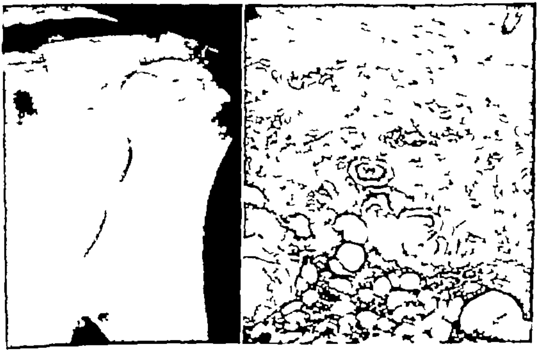

Fig. 319 (*Left*) Osteochondroma of upper end of the humerus of a male aged 12 Single lesion. (*Right*) Benign osteochondroma showing typical structural picture The outer portion is composed of hyaline cartilage which at a lower level exhibits calcification the inner portion or base consists of cancellous bone. The cartilaginous cap is covered with a layer of connective tissue (not seen in this section) (Photomicrograph × 125)

The patient (male 12 years of age), whose shoulder is depicted in Figure 319 was unaware of the tumor but experienced some soreness and stiffness in the shoulder region following each game of baseball The pain disappeared with rest but the patient felt numbness in the hand on several occa sions following severe exertion

The clinical manifestations are generally caused by the tumor pressing on the sur rounding structures. Local paralysis may be the first indication This was demonstrated by case J D, male 6 years of age The mother sought medical aid because of a prominence of the right shoulder blade Ex amination disclosed paralysis of the serratus anticus muscle and a large irregular osteo-chondroma on the ventral surface of the scapula Skeletal survey revealed multiple bone lesions with involvement of the upper ends of both humeri (Fig 320) Excision of the bone tumor on the scapula was followed by return of power in the affected muscle (Fig 35)

Changes in the character of the tumors such as pain and increase in size are ominous signs Although this group of tumors is essentially benign sarcomatous degeneration occurs more frequently than realized

Fig 320 Osteochondroma of upper end of the humerus of a male aged 6 one of multiple lesions affecting all long bones and right scapula.

Roentgenographic Features

Radiographically the osteochondroma re veals rather distinctive characteristics It may be portrayed as a bony protuberance continuous with the shaft of the humerus by a narrow pedicle or by a broad base the latter variety constitutes the sessile form (Figs 319 and 320) The base of the tumor is composed of normal bone its periphery, however is covered by a cartilaginous cap in which may be seen irregular calcified areas. Varying degrees in the size of the cartilaginous covering are discernible in dif ferent tumors The tumor may exist as a narrow regular, imperceptible band or an enormous irregular calcifying lesion, often referred to as a "cauliflower mass" In benign lesions the periphery is sharply de-fined and the base shows a normal bone pattern An irregular, hazy ill-defined pe-riphery a granular stippled appearance of the cartilaginous elements and irregular areas of bone resorption at the base of the tumor are suspicious indications of malig nant transformations

Treatment and Prognosis

Small asymptomatic tumors require no treatment Tumors which interfere with normal function of the shoulder or press on surrounding structures sufficiently to cause pain should be removed Excision of the mass should be complete and should be per formed through normal osseous tissue beyond the limits of the tumor Big tumors with large cartilaginous caps may not be

ing of an important tendon At such a juncture nature normally provides a protuberance of bone bulging through a gap in the periosteum to meet an adjoining tendon which co-operates in the formation of the attachment by cartilaginous ossification within the substance of the tendon [1] They state that in multiple exostosis "tags of perichondrium in the tendon ends proliferate to form cartilaginous and bony outgrowths Disturbances and deficiencies in the periosteum in the metaphyseal regions lead to widening of the metaphysis and inhibition of bone growth "[2]

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Clinical Features

Many lesions are asymptomatic and are discovered only accidentally by roentgenographic examination of the affected region for reasons unrelated to the neoplasm. The patient may or may not be aware of the tumor s presence Occasionally some form of injury directs his attention to the neoplasm.

Quiescent lesions can exist for many years without clinical manifestations some may never give rise to symptoms. Large tumors in the region of the upper end of the humerus may interfere with motion at the shoulder joint In these cases palpation usually discloses a firm painless more-or less symmetric mass attached to the underlying bone The consistency of the mass depends upon the amount of cartilaginous tissue Soft tissues are freely movable over the mass

[1] C F Geschickter and M M Copeland, Tumors of the Bone ed 3 Philadelphia, Lippincott, 1949 p 77

[2] *Ibid* p 86

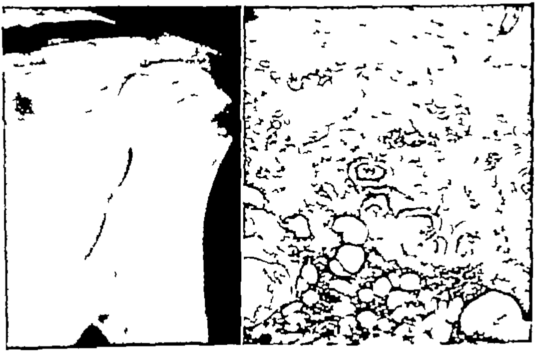

Fig. 319 (*Left*) Osteochondroma of upper end of the humerus of a male aged 12 Single lesion (*Right*) Benign osteochondroma showing typical structural picture. The outer portion is composed of hyaline cartilage which at a lower level exhibits calcification the inner portion or base consists of cancellous bone. The cartilaginous cap is covered with a layer of connective tissue (not seen in this section) (Photomicrograph × 125)

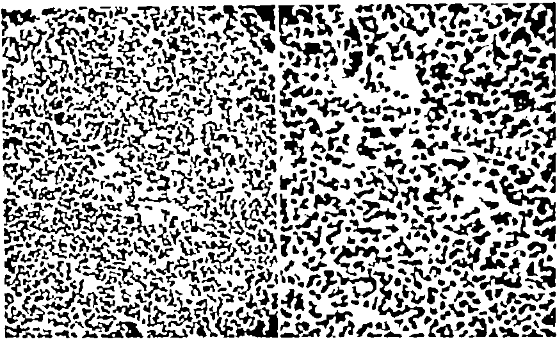

FIG 321 Plasma cell myeloma Observe the globular eccentrically placed nuclei (Photomicrographs × 125 and × 250)

manifestations and of the long bones particularly the femur and the humerus are common sequelae occurring in myelomas more frequently than in any other bone tumors (in over 50 per cent of the cases) Multiple fractures are not uncommon In widespread skeletal involvement small semifluctuant tender tumors may be palpable in the ribs the sternum or the clavicle and the shafts of long bones may reveal uniform palpable distensions

Systemic reactions through involvement of the blood forming elements and viscera may give rise to fever malaise and loss of weight Bence Jones bodies are found in over 50 per cent of the cases these proteins have also been found in such other diseases as leukemia carcinoma with skeletal metastases multiple sarcoma of bone (Seegelken Gilmore) polyfibrocystic disease (Grooves) comminuted fracture (Campbell and Horsfall) and senile osteomalacia (Rascke)

As the result of extensive destruction of the hemopoietic elements varying degrees of secondary anemia are constant manifestations of the disease Serum protein level may be above normal limits in many cases occasionally it is markedly elevated

The disease pursues a variable course

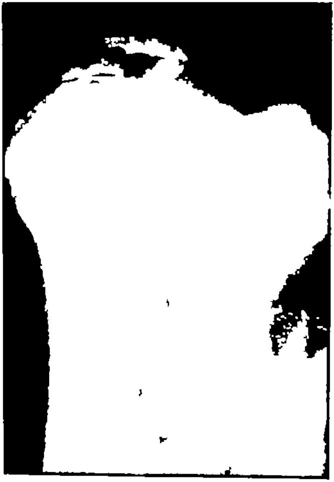

FIG 322 Multiple myeloma (plasma cell myeloma) of the shaft of the humerus Note osteolytic nature of the lesion with no evidence of repair also the numerous discrete punched out radiolucent areas and thinned cortex

amenable to local excision resection of these lesions, if possible is justifiable If histologic examination gives definite evidence of sarcomatous degeneration the lesion is treated as outlined in the treatment of secondary chondrosarcomas

The most significant change indicative of early malignant transformation is a gradual increase in the size of the tumor Therefore, known lesions should be checked radiographically at regular intervals to note any alteration in their physical character Since malignant changes usually occur after 30 years of age this check up study is more essential in adults than in children

MULTIPLE MYELOMA

Introduction

Multiple myeloma (plasma-cell myeloma) is truly an endosteal tumor It arises from the blood forming elements of the bone marrow and it is multifocal in origin The disease is extremely malignant and although pain may be controlled sometimes and life may be prolonged by roentgen therapy the outcome is invariably fatal Plasma-cell myeloma is the most common of four varieties the others in order of frequency are myelocytoma lymphocytoma and erythroblastoma According to Coley the plasma-cell tumor constitutes 95 per cent of all myelomas

The causative factors of the myelomas are obscure Some investigators contend that they are not true primary bone tumors but diseases of the lymphoid system (Meyerding) or of the lymphatic hemopoietic system (Lubarsch) In the differential diagnosis several entities may be confused with this tumor metastatic carcinoma offering the greatest difficulty Giant-cell tumor is mentioned in the differential diagnosis when radiographic examination in the early stages shows only a single bone lesion At times, Ewing's tumor must be considered in arriving at a diagnosis. However the age of the patient (usually over 40 years) the presence of Bence-Jones protein in the urine (over 50 per cent of the cases) and histologic examination of the bone marrow (obtained by sternal or iliac puncture or open biopsy) suffice to establish the diagnosis in the majority of cases.

Incidence, Age and Sex

This tumor is more common than is generally appreciated Such improved diagnostic aids as sternal, iliac puncture and roentgenographic examination make possible the diagnosis of many lesions hitherto undiagnosed or erroneously diagnosed The tumor is rarely encountered in those under 35 years of age usually it is found in those over 40 its highest incidence being in those between 56 and 60 years Males are more commonly affected than females the ratio is roughly 3 to 1

The bones which most frequently disclose clinical and radiographic manifestations of the disease are in the order of frequency the vertebrate the ribs the pelvis the femur and the humerus

Clinical Features

Vague pain in the lower back the abdomen and the chest may be the only complaints early in the disease. Weakness, malaise and loss of weight may be associated symptoms because of the progressive anemia Pain may be mild at first may increase progressively in intensity and as a rule it is aggravated by exertion Rest generally gives relief nocturnal pain not being a characteristic feature Pain may be intermittent In fact periods of remission which may last for months with or without treatment are common While the interval is usually under a year cases have been recorded in which the remission lasted for 3 to 5 years

The onset of the disease may be ushered in by a pathologic fracture (in rare cases) by the presence of a tumor or by severe pain following some form of activity Pathologic fractures are encountered most frequently in the ribs Fracture of vertebrae, which may be accompanied by neurologic

FIG 323 Osteoblastic metastatic foci in bones of the shoulder girdle from cancer of the breast (P Swenson Jeffer son Medical College)

FIG 324 Osteolytic metastatic lesions in scapula from cancer of the breast. (H Ostrum, Philadelphia General Hospital)

evidence of bone involvement before death It is generally known that carcinoma of certain viscera are more prone than others to metastasize to bone Breast lesions frequently affect bone while carcinomas arising in the prostate do so less frequently malignancies of the bladder the cervix the uterus and the gastro-intestinal tract rarely show this tendency In 1922 Kauffmann noted on postmortem investigation that approximately two-thirds of all breast cancers and one half of all prostatic malignancies disclosed skeletal metastases

Bones comprising the shoulder girdle are common sites for metastatic lesions In fact renal carcinoma metastasizes to the humerus particularly to its upper third, more frequently than to any other bone of the body Carnett and Howell (1930) reported a series of breast cancers in which the humerus and other bones of the shoulder girdle disclosed an unusually high incidence of involvement

Secondary bone involvement may be the first clinical manifestation of cancer elsewhere Not infrequently the primary lesion may never be uncovered, even at autopsy

TYPES OF METASTATIC BONE LESIONS

Secondary metastatic lesions in bone are most often multiple however, occasionally single lesions are encountered If single lesions are followed for sufficient time almost always multiple involvement will be demonstrable ultimately According to Geschickter and Copeland, single lesions occur in 25 per cent of breast cancers and they are observed more frequently in renal cancers. Although any bone in the body may be affected secondarily by any of the recognized types of cancer in general certain cancers show a predilection for specific skeletal regions Thyroid and renal cancers most frequently metastasize to the long bones of the extremities particularly the humerus and the femur breast and prostatic tumors metastasize to the spine and the pelvis Metastatic foci in bone may be either osteoblastic or osteolytic in nature

As a rule cancer cells are deposited in the

usually lasts less than two years and terminates in death

Pathology

The tumor originates from multiple foci in the cancellous spaces and the medulla and comprises a soft, gelatinous substance which varies in color (gray, brown or red), depending upon its vascularity In the spongiosa, the points of origin grow, expand and cause resorption of the surrounding bone trabeculae and become confluent The cortex is slowly resorbed and thinned the periosteum is distended Codman aptly describes the process The result is an appearance as if the bone were blown from inside as by a series of bubbles, large and small Characteristic of this group of tumors there is no reactive bone formation

Histologic examination reveals a fairly constant pattern It consists predominantly of large round or ovoid plasma cells with globular nuclei placed eccentrically and chromatin material arranged in "spokelike" fashion at the peripheries (Fig 321)

Roentgenographic Features

Roentgenograms of multiple myeloma are fairly characteristic As in other bones of the skeletal system those of the shoulder girdle exhibit numerous discrete punched out radiolucent areas of varying size Lack of reactive new bone formation around the lesions is a prominent and striking feature The lesions arise in a more-or less central position destroy all bone they come in contact with and slowly but uniformly expand the shaft (Fig 322)

The lesion is truly an osteolytic neoplasm hence its radiographic similarity to giant cell tumors osteolytic sarcomas and osteolytic metastatic carcinomatous lesions Fracture of the bone through the affected area may occur in these cases evidence of bone healing even if present is not marked

Prognosis and Treatment

The prognosis is always poor Moderate dosages of irradiation can alleviate pain and induce remissions. Surgery has nothing to offer except to obtain material for histologic study, either by open biopsy or aspiration. Treatment is entirely expectant in nature. In the event of fracture, protection of the humerus by splints or a plaster cast may be necessary In fractures of the humerus, as in fractures of other tubular bones, the insertion of a Küntscher nail in lieu of cumbersome casts, splints or traction apparatus may be justifiable to obtain fixation in these debilitated patients

SOLITARY PLASMA-CELL MYELOMA

Such lesions have been recorded in the literature, but the author never has seen one which did not ultimately develop multiple bone involvement Posternack and Waugh (1939) reported 30 cases from the literature and one of their own In this series the humerus was involved in 4 cases and the clavicle in 1 It is apparent that a single lesion may offer considerable diagnostic difficulties. Its osteolytic and expansive nature may readily confuse it with giant-cell tumor and some varieties of metastatic carcinomatous lesions

The afore-mentioned investigators noted that solitary lesions have a more favorable outlook. Seven of their cases were alive from 4 to 10 years and 6 from 7 to 10 years later However when considering the prognosis of a solitary myeloma one should be cognizant of the fact that the osseous lesion is only one manifestation of a generalized affection of the hemopoietic system.

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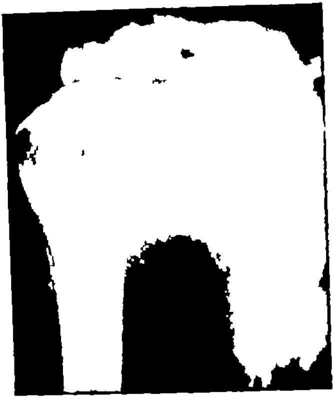

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of the opinion that most cases diagnosed as Ewing's tumor are actually cases of neuroblastoma

Pathologic Fractures

Fracture of the bones of the shoulder girdle especially the humerus is a serious complication because it adds to the difficulty in the treatment of the patient It is a common sequela of metastatic carcinoma and multiple myeloma and may be the first indication of the disease In fact a pathologic fracture produced spontaneously or following trivial trauma in an individual past 35 years of age is in most instances the result of metastatic carcinoma or multiple myeloma The incidence of pathologic fracture is unusually high in metastatic renal carcinoma Some investigators series report an incidence as high as 45 5 per cent the humerus holding second place in the order of frequency of fracture Prostatic cancer rarely is associated with fractures most of the metastatic lesions are characterized by new reactive bone formation and are less prone to sustain fractures

Treatment of pathologic fracture in the bones of the shoulder girdle does not differ from pathologic fractures in other bones of the body Intramedullary pinning with a Küntscher nail for fracture of the humerus has been used by the author This facilitates management of the patient alleviates pain and does not interfere with other forms of therapy

Spontaneous healing occurs occasionally The amount of new bone is usually small and defective and refracture is the usual sequela In some cases roentgen ray therapy undoubtedly destroys the tumor cells or inhibits their activity sufficiently to allow healing Endocrine therapy and castration have been known to produce rapid bone regeneration and tumor regression in many instances of breast and prostatic tumors

Roentgenographic Features

Multiple skeletal lesions in an individual past 35 years are usually indicative of metastatic carcinoma or multiple plasma cell myeloma The latter lesion is portrayed radiographically by multiple discrete punched out radiolucent areas without evidence of new bone formation Solitary plasma cell myeloma may cause considerable expansion of the humeral shaft resembling osteolytic metastatic carcinoma Diagnosis can be established by histologic study of the local tumor tissue and of the bone marrow obtained by sternal or iliac puncture

Osteolytic solitary metastatic carcinoma lesions of the upper end of the humerus especially of renal or thyroid origin may be confused with osteolytic osteogenic sarcoma malignant giant cell tumors or a latent bone cyst Osteoblastic lesions especially those of prostatic cancer may closely resemble osteoblastic osteogenic sarcoma It is obvious that histologic study of the tumor tissue is essential to establish a correct diagnosis Blood studies revealing an elevated acid phosphatase level point to prostatic cancer

MYOSITIS OSSIFICANS CIRCUMSCRIPTA

Introduction

This variety of myositis ossificans follows single or repeated trauma Although the brachialis anticus and quadriceps femoris muscles are most frequently affected the lesion is not uncommon in the deltoid muscle The fact that this lesion has often been confused with periosteal osteogenic sarcoma and (through this erroneous diagnosis occasionally has been treated by amputation) makes it imperative that the lesion be considered in this chapter dealing with bone neoplasms in the region of the shoulder joint Myositis ossificans (especially in the early stages) may simulate osteogenic sarcoma so closely in rare instances that both surgeon and pathologist may not be able to establish a correct diagnosis in spite of all the clinical radiographic and histologic evidence before them

Cases are on record however in which

FIG 325 Metastatic lesion to the upper end of the shaft of the humerus from cancer of the kidney The lesion is osteolytic in nature has caused marked expansion of the shaft and produced a pathological fracture. It must be distinguished from the osteolytic form of osteogenic sarcoma. (H. Ostrum.)

FIG 326 Metastatic foci to the scapula from carcinoma of the prostate gland Observe the osteoblastic nature of the tumor (H. Ostrum.)

cancellous bone of the ends of long bones and in the region of the nutrient artery Hyperplasia of the tumor cells may stimulate varying amounts of reactive new bone formation from the endosteal and periosteal elements Cancers producing such a response are referred to as osteoblastic tumors The involved bone areas reveal irregular areas of increased density and irregular thickening of the cortex also they may exhibit periosteal new bone above and below the lesion (Fig 323) On the other hand some skeletal metastatic lesions produce no reactive new bone formation, the tumor being purely a destructive lesion. Starting from a central position it first destroys the spongiosa then erodes the cortex expands to the shaft and perforates the periosteum (Fig. 324)

These lesions comprise the osteolytic group They are considered to grow more rapidly to attain greater dimensions than osteoblastic tumors and to be more frequently associated with pathologic fractures (Fig 325) Metastatic tumors of the prostate are most often osteoblastic (Fig 326) However some prostatic cancers may be osteolytic others may exhibit both characteristics A goodly number of breast cancers also exhibit osteoblastic tendencies, most of them being osteolytic. Renal and thyroid cancers generally give rise to osteolytic metastatic lesions

Ewing s tumor and neuroblastoma of adrenal or sympathetic origin should be mentioned in discussing types of metastatic lesions These tumors are the source of metastatic skeletal lesions essentially osteolytic in nature especially in the tubular bones While the age period in which they occur and their histologic features usually distinguish them readily from metastatic carcinoma it may be exceedingly difficult to differentiate one from the other Willis is

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sarcomatous changes occurred in areas of myositis ossificans many years after the initial trauma. Pack and Braund reported two cases in which both patients died of pulmonary metastasis. Shipley recorded 4 cases Geschickter and Copeland 2 (one of which was in the deltoid muscle) Coley has observed 1 unquestionable case

Age, Sex and Site

The brachialis anticus the quadriceps femoris and the deltoid muscles constitute the site of predilection. It is seldom observed in very young children or in the aged The highest incidence occurs between 15 and 20 years but is fairly common up to 40 The highest incidence apparently coincides with the period in life in which most strenuous bodily exertion takes place Injuries sustained in football and soccer are frequently the inciting traumas Males are far more frequently affected than females.

Clinical Features

There is always a definite history of rather severe trauma followed by tumefaction of a localized area in the deltoid muscle The mass is at first tender but not very prominent Later it slowly increases in size and acquires a hard bony consistency At this stage pain is not a significant feature and recession of the tumor may occur It rarely disappears completely

Roentgenographic Features

Roentgenograms immediately following an injury fail to reveal any significant findings Within 2 to 4 weeks evidence of calcification becomes apparent in the muscle If a subperiosteal hemorrhage is present the above process is also visible along the shaft of the humerus Ferguson is of the opinion that trauma in soft tissues is responsible for stagnation of body fluids and calcification at first diffuse and amorphous, later more sharply defined dense and discrete The deposit develops an osseous pattern if subjected to functional stresses Hence, in myositis ossificans traumatica of the deltoid the calcareous mass is "distributed axially" and extends along the muscle fibers parallel with the humeral shaft It becomes more sharply defined as an osseous texture forms Generally in old cases the osseous structure is well laminated regular in outline and is apart from the shaft of the humerus lying entirely within the deltoid muscle In rare instances it may be attached to the bone for varying distances and its outline may be irregular and fuzzy Such cases may cause considerable concern in attempting to arrive at a correct diagnosis.

Early cases may challenge the most experienced investigators but late cases rarely present difficulty especially in the light of a history of severe injury When in doubt a period of waiting is justifiable before any therapy is instituted Repeated roentgenographic examinations at frequent intervals will reveal the nature of the lesion in 3 to 6 weeks which—together with the features of the clinical course pursued within this period—will aid in establishing a diagnosis.

Treatment

No treatment except rest to the part, is indicated in unquestionable cases. Surgical intervention in the early stages of the disease is contraindicated since the entire process may be stimulated to renewed activity and tumor recurrences Excision of the mass may be performed late in the disease when all evidence of activity has subsided Open biopsy is justifiable in doubtful cases

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It is obvious therefore that surgical intervention is not indicated in the above lesions until there is definite clinical evidence of shoulder joint dysfunction resulting from extensive tears of the cuff. Impacted fractures of the upper end of the humerus do not require reduction; excellent painless motion without normal anatomic repositioning of the fragments is the rule.

However, a group of lesions do demand primary surgical intervention; recognition and prompt and adequate management of these conditions will produce gratifying results. The surgeon's failure to so proceed results in marked dysfunction of the shoulder joint. This is especially true of fracture-dislocations of the humeral head, fracture of the greater tuberosity with retraction beneath the acromion, and extensive tears of the musculotendinous cuff which may occur with simple dislocation or fracture-dislocations.

Accurate diagnosis cannot be made in many instances, yet exploration of the subacromial region is indicated. In other cases visualization of the affected area may disclose unsuspected pathologic disorders at great variance with what the surgeon anticipated preoperatively. It becomes apparent that the operator must be well trained and experienced in surgery of the region of the shoulder joint and be prepared to treat adequately all lesions that may be encountered.

Knowledge and proper management of certain peculiarities of this region will prevent undesirable sequelae and promote restoration of function. Immobilization of the shoulder joint favors formation of adhesions in and between the strata of soft tissues comprising the shoulder, obliteration of the gliding parts between the various strata, formation of periarticular adhesions and contracture and shortening of the muscles, particularly the adductor group. All surgeons recognize the seriousness and the disability of a stiff painful shoulder. Therefore operative procedures should strive for early mobilization of the part, which is the best and only prophylactic measure at our disposal.

It has been pointed out that frozen shoulder is more apt to occur in individuals past 30 years of age, in those whose general economy is below par and in those who are victims of chronic debilitating diseases. Maintenance of normal motion in the joints distal to the shoulder, good tonicity of the muscles and elasticity of other soft tissues of the limb will enhance rapid restoration of function at the shoulder joint. Rigid and complete postoperative immobilization of the upper extremity must be avoided at all times unless it is an absolutely essential requirement in the plan of treatment. Active exercises and use of the extremity are far superior to any passive forms of physiotherapy.

ANATOMIC CONSIDERATIONS

Principal Gliding Mechanisms

From a practical viewpoint, the muscles of the shoulder region form two sleeves; one glides within the other. The deltoid muscle is the principal component of the outer sleeve while the short rotator muscles (supraspinatus, infraspinatus, teres minor and subscapularis muscles) comprise the inner sleeve. Between the two is an efficient gliding mechanism which allows free smooth unrestricted movements. This mechanism consists of the subacromial bursa (see Anatomy of Subacromial Bursa) and loose fine areolar tissue. To insure maximum function it is essential to preserve this gliding mechanism. However, as previously pointed out, part or all of the superior walls of the subacromial bursa may be removed without ill effects. There exists another gliding mechanism in this region which plays a major role in movements of the scapulohumeral motion, namely the tendon-tendon-sheath apparatus of the long head of the biceps brachii muscle.

It will be recalled that the synovial lining of the scapulohumeral joint continues distally in the bicipital groove and is then

11

Surgical Approaches and Procedures

GENERAL CONSIDERATIONS

The goal of all operative procedures in the region of the shoulder joint is to restore maximum painless function approaching the normal Failure to attain this end results in marked impairment in the usefulness of the hand a highly specialized organ which depends for optimum performance upon the integrity of the shoulder joint Essentially the principal function of the upper extremity is to place and maintain the hand in positions necessary to execute specific duties To achieve this goal certain prime requisites are mandatory

All surgical procedures must be governed by an accurate knowledge of the topographic anatomy and comprehension of the functional mechanics of the structures for which surgery is contemplated So intimately interrelated are the structures comprising the shoulder joint that dysfunction of one will be reflected in the total performance of this complex mechanism On the other hand an appreciation of the alterations compatible with good function possible in this region will facilitate some surgical procedures and permit certain modifications of normal anatomy

For example it has been demonstrated *clinically that removal of all or portions of* the acromion in no way affects the efficiency of the deltoid muscle this fact also allows resection of the bony prominence with impunity when greater exposure of the subacromial region is desired Also the coracoacromial ligament may be severed or resected and portions or all of the roof of the subacromial bursa excised without impairing the normal, smooth rhythmical movements of the shoulder joint. (In Chapter 3 the functional mechanics of the shoulder joint have been considered)

Operative procedures are not justifiable without assurance that function will be improved Such procedures are contraindicated if their aim is primarily to restore normal anatomy without improving function As has been shown within certain limits tears of the musculotendinous cuff are compatible with complete painless motion of the shoulder Fresh traumatic lesions pointing to rupture of the cuff do not demand immediate exploration of the subacromial area Many individuals so afflicted regain complete usefulness of the arm after the acute painful symptoms subside, if the tear is not too severe.

the muscle substance alternating with those passing downward The oblique fibers arising from the descending septa insert into the ascending septa Such a complex scheme does not exist in the anterior and posterior portions of the deltoid muscle Between the adjacent borders of the deltoid and the pectoralis major muscles is a distinct interval which widens at its proximal end to form the inferior clavicular fossa or deltopectoral triangle

Cephalic Vein

The cephalic vein traverses the deltopectoral groove picking up tributaries as it proceeds cephalad It occupies progressively a lower level as it ascends until it lies on the clavipectoral fascia below the calvicle it perforates the costocoracoid fascia passes anterior to the axillary artery and empties into the axillary vein The cephalic vein is a landmark in surgical procedures in this region it points to a natural plane of cleavage to the structures at a lower level The axillary vessels are readily identified by tracing the cephalic vein upward The origin of the deltoid muscle is of practical significance It originates in the clavicle the acromion and the spine of the clavicle and consists of tendinous fibers which blend with the periosteum of these bony structures. Part or all of the origin of the muscle may be detached subperiosteally and still sufficient sturdy tissue remains to effect firm reattachment of the muscle on either side of the line of division

Pectoralis Major

The pectoralis major is the large fan shaped muscle covering the upper and anterior portions of the thoracic cage It is composed of muscle fibers arising from three origins The clavicular portion takes origin from the anterior surface of the inner half of the clavicle the sternal portion from the anterior surface of the sternum the cartilages of the first seven ribs and the abdominal portion from the aponeurosis of the oblique externus abdominis All fibers are directed laterally converging as they near the shaft of the humerus They insert into the crest of the greater tuberosity by means of a broad flat bilaminar tendon U shaped whose layers are continuous below but opened above The anterior lamina is formed by the fibers of the clavicular and the upper sternal portions of the muscle the fibers from the abdominal and lower sternal portions forming the posterior lamina which ascends to a higher level than the anterior lamina and giving off fibers—both those which span the intertubular groove and others which are continuous with the fibrous capsule of the glenohumeral joint

Bony Landmarks

Four bony eminences are the landmarks for all operative procedures in this region. These are the acromion process the greater and the lesser tuberosities and the coracoid process The acromion process forms the tip of the shoulder and overhangs the greater and the lesser tuberosities all are readily palpable The coracoid process lies immediately beneath the anterior border of the deltoid muscle It is situated in the interval formed by the clavicle and the inner aspect of the head of the humerus one fingerbreadth below the inferior margin of the clavicle It too is easily felt The conjoined tendon of the short head of the biceps brachii muscle and the coracobrachialis arises from the coracoid process into which is inserted the pectoralis minor muscle.

This process is an important guide to the large vessels and nerves of the arm which pass under cover of the pectoralis minor to the inner aspect of the coracoid process thence to the inner side of the coracobrachialis. Forceful retraction of the muscles attached to the coracoid process may inflict trauma to the adjacent nerves and vessels The author has observed several cases of severe causalgia which developed postoperatively as a result of prolonged and forceful traction on these structures

Other bony landmarks are the spine of

reflexed proximally onto the biceps tendon The old concept that the tendon glides in the groove has given way to the newer opinion that the humerus slides up and down the tendon during all motions at the significance of this gliding plane is evident when it is converted into dense, plastic adhesions which bind the short rotator muscles to the capsule, a condition notable in frozen shoulder

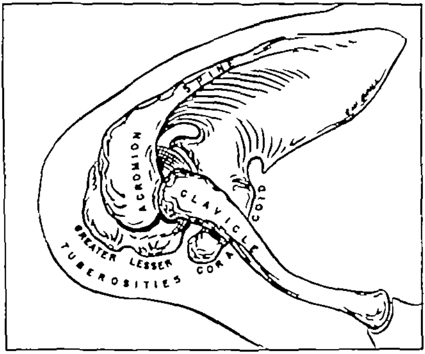

FIG 327 Bony landmarks of the shoulder girdle

scapulohumeral joint and that although the biceps tendon becomes taut during these motions it does not move within the groove Interference with free excursion of the humeral head on the tendon results in marked impingement of elevation of the upper extremity Yet it has been shown that total obliteration of this mechanism by anchoring the biceps tendon to the humerus or coracoid process is compatible with painless normal range of motion

It was previously noted that the four short rotator muscles (supraspinatus infraspinatus teres minor and subscapularis muscles) terminate in short stout tendons which blend with one another and with the fibrous capsule to form the musculotendinous cuff Proximal to the line of fusion of the tendons with the capsule the muscles lie directly on the fibrous capsule the two structures are separated only by a layer of filmy areolar tissue which permits the two strata to glide *by one another* with minimum friction during movements of the limb The

Deltoid Muscle

The deltoid which forms the outer of the two muscular sleeves is a massive triangular muscle which drapes itself around the anterior lateral and posterior aspects of the outer third of the clavicle the lateral border of the acromion process and the lower border of the spine of the scapula. Its fleshy fibers converge distally to form a stout short tendon which inserts into the deltoid tubercle The arrangement of the anterior and posterior fibers of the deltoid which arise from the clavicle and the spine of the scapula respectively differs from that of the central fibers which arise from the acromion

The central muscle mass consists of oblique fibers which arise pinnate fashion from either side of 4 to 5 tendinous bands whose proximal ends are attached to the acromion These fibrous septa proceed distally parallel with one another and become lost in the muscle substance From the tendinous insertion of the deltoid 3 or 4 similar tendinous strands pass upward into

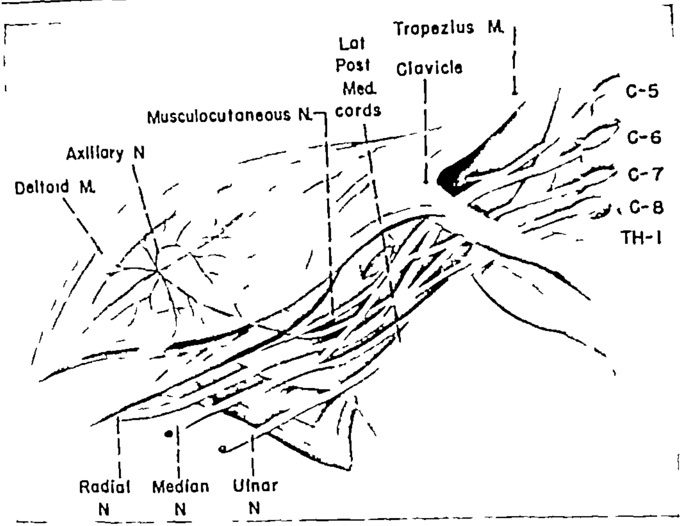

FIG 328 Course of the axillary nerve around the neck of the humerus.

the integument over the lower posterior and lateral portions of the deltoid (Figs 206 and 207)

The anterior branch together with the posterior humeral circumflex artery winds around the surgical neck of the humerus giving off muscular branches which pass vertically upward into the substance of the deltoid muscle As it approaches the anterior border of the deltoid it diminishes progressively in size Throughout its entire course from its origin posteriorly to its termination anteriorly the anterior division runs a horizontal course roughly 2 inches below the lateral border of the acromion process (Fig 328)

It becomes apparent that a zone of safety exists between the course of the nerve and the origin of the deltoid which can be utilized in surgical approaches to the subacromial region and to the glenohumeral joint From a practical viewpoint incisions in the anterior aspect of the deltoid (from ½ to ¾ inches from the anterior border of the muscle) which cross the path of the axillary nerve do not in any way diminish the efficiency of the muscle This is not true if the nerve is severed in its anterolateral, lateral or posterior position

The suprascapular nerve is formed by fibers derived from the fifth and the sixth cervical nerves under cover of the trapezius and the omohyoid muscles. The nerve proceeds laterally and passes beneath the superior transverse scapular ligament to reach the supraspinous fossa In this position it lies in relation with the transverse scapular artery (a branch of the thyrocervical trunk) which passes above the suprascapular ligament Both nerve and artery then proceed beneath the supraspinatus muscle In this position the nerve gives off branches to the supraspinatus muscle and twigs to the shoulder joint It then winds around the spine of the scapula to the infraspinous fossa where it supplies branches to the infra

the scapula and the clavicle, both are subcutaneous and readily palpable throughout their entire lengths The acromion and the spine of the scapula together with the clavicle form the arch of the shoulder

Both the acromioclavicular and the sternoclavicular joints occupy very superficial positions and are readily palpated as compared with the glenohumeral joint which is situated at a much deeper level and cannot be palpated The acromioclavicular joint is recognized by the enlarged outer end of the clavicle which articulates with and projects above the flat superior surface of the acromion The sternoclavicular joint is identified by the enlarged sternal end of the clavicle which is readily felt immediate to the outer border of the sternal head of the sternocleidomastoid muscle

Subacromial Bursa

Other structures of surgical significance are situated under cover of the deltoid muscle These are the coraco-acromial ligament the subacromial bursa the musculotendinous cuff and the long head of the biceps brachii These structures have been considered in detail in Chapter 2 However attention again must be called to the topographic anatomy of the subacromial bursa It is a concave-convex structure whose floor is firmly attached to the superior surface of the musculotendinous cuff and the greater tuberosity while its roof is adherent to the under surface of the deltoid muscle It is prolonged under the coraco-acromial ligament and the acromion It may extend medially as far as the base of the coracoid process, this portion is often referred to as the subcoracoid bursa

Incisions through the anterior and lateral aspects of the deltoid muscle may open the roof of the bursa unless great care is exercised in separating it from the overlying muscle fibers. However in order to gain access to that portion of the musculotendinous cuff beneath the acromion it will be necessary to split the superior wall of the bursa.

Musculotendinous Cuff

The fibers of the tendons of the short rotator muscles intermingle with the fibers of the capsule proximal to their point of insertion to form the musculotendinous cuff This inserts into the sulcus of the head of the humerus and the greater and the lesser tuberosities Between the subscapularis and the supraspinatus tendons is an interval occupied by the coracohumeral ligament. This break in the continuity of the cuff provides an excellent approach to the inside of the glenohumeral joint, the exposure being attained by dividing the capsule in the above interval parallel with the fibers of the coracohumeral ligament Such an incision can be extended readily as far as the brim of the glenoid cavity

Nerves

The topographic anatomy of the nerves supplying the structures of the shoulder joint must be constantly in the mind of surgeons working in this region. Damage to these structures results in marked dysfunction of the upper extremity The axillary, the suprascapular and the musculocutaneous nerves are most vulnerable during operative procedures

All surgical approaches to the shoulder joint are more or less designed around the course of the axillary nerve. Its fibers are derived from the fifth and the sixth cervical nerves which traverse the posterior cord Posterior to the axillary artery at the lower border of the subscapularis muscle the posterior cord gives off the axillary nerve. This together with the posterior humeral circumflex artery passes backward through the quadrilateral space thence winds around the surgical neck of the humerus and under cover of the deltoid muscle reaches the anterior aspect of the shoulder At its exit from the quadrilateral space it divides into anterior and posterior branches

The posterior branch innervates the teres minor and the posterior portion of the deltoid It then continues laterally as the lateral brachial cutaneous nerve supplying

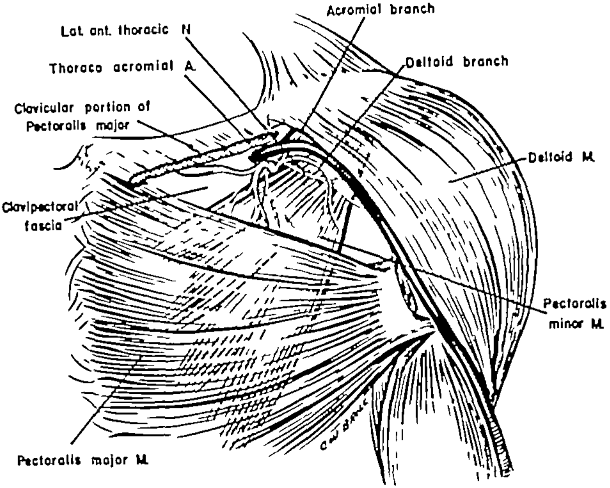

FIG 330 The costocoracoid membrane.

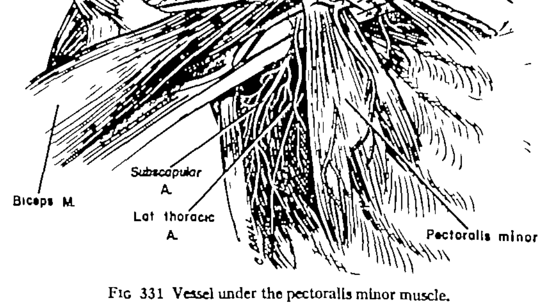

FIG 331 Vessel under the pectoralis minor muscle.

spinatus muscle, the capsular ligaments of the shoulder joint, and the scapula (Fig 329)

The musculocutaneous nerve is composed *of fibers from the fifth, sixth and seventh* cervical nerves and comes off the lateral cord below the lower margin of the pectoralis minor muscle close to its insertion into the coracoid process It passes through the substance of the coracobrachialis muscle to the lateral aspect of the arm between the biceps brachii and the brachialis muscles This nerve may be traumatized by surgical procedures in the anterior region of the shoulder in which *traction in a medial direction is made on the structures* attached to the coracoid process (Fig 209)

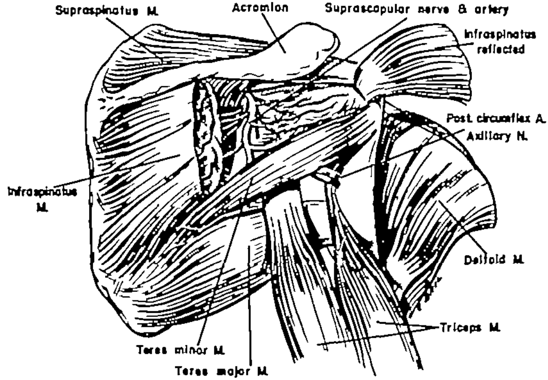

Fig 329 Course of the suprascapular nerve

Arteries and Veins

The acromiothoracic artery (a branch of the second part of the axillary artery) the cephalic vein and the lateral anterior thoracic nerve are beneath the clavicular origin of the pectoralis major muscle All pierce the costocoracoid membrane (part of the clavipectoral *fascia*) in their respective courses The cephalic vein pierces the fascia and empties into the axillary vein, therefore acting as a useful guide to the large vessels the acromiothoracic artery (after passing through the fascia) gives off the pectoral, the acromial, the deltoid and the clavicular branches When working in this region careful dissection isolation and ligation of these vessels will eliminate profuse bleeding (Figs 330 and 331)

The anterior and the posterior humeral circumflex arteries both branches of the axillary artery must be given due consideration in surgical procedures in this region. As previously noted the posterior humeral circumflex *is in intimate relationship with the axillary* nerve *throughout its entire* course It is larger than the anterior humeral circumflex artery and arises from the axillary artery at the lower border of the subscapularis muscle Together with the axillary nerve it proceeds backward through the quadrilateral space formed by the teres major below the subscapularis and the teres minor above the long head of the triceps brachii medially and the surgical neck of the humerus laterally It passes around the neck of the humerus anastomosing with the

shoulder with maximum efficiency and ease The ideal position permits easy access to the anterior the lateral the posterior and the superior aspects of the shoulder maintains the patient s head in a fixed position away from the operative field allows manipulation in all directions of the affected extremity and finally permits two assistants to work without obstructing the field Many surgeons still utilize the supine position, with a sandbag under the shoulder This position does not provide the helpful features enumerated Moreover it adds to the surgeon s difficulties by failing to provide ready access to the lateral, the superior and above all the posterior regions of the shoulder Then too the surgeon and his assistants are forced to work in awkward and strained positions

Of all the positions the sitting position has proved to be closest to the ideal posture A tilting operating table is necessary The upper part of the table beneath the patient s trunk is raised to an inclined plane of 60° to 70° from the horizontal and the lower part is broken and elevated under the knees so that both hips and knees are flexed sufficiently to prevent the patient sliding down on the table. The patient is placed so that the shoulder extends over the side of the table By tilting the whole table slightly away from the surgeon accessibility to all parts of the shoulder is increased The head is turned to the opposite side and the arm is draped separately to permit manipulation of the extremity (Fig 332) This position has proved to be most practical for all surgical procedures on the shoulder

In cases in which the operative procedure is to be limited entirely to the anterior aspect of the shoulder such as removal of calcareous deposits from the musculotendinous cuff or exploration of the subacromial bursa the supine position with the shoulder over the side of the table and a sandbag under it suffices The prone position may be used if the procedure is restricted to the posterior aspect of the shoulder Here the outstretched arm is placed on a table or arm board a sandbag is placed under the chest wall on the affected side and the head is turned to the opposite side

Draping the arm correctly so as to permit manipulation appears to be an insignificant step in preparation of the patient Yet it detracts from the smoothness of the operation if not properly done Otherwise the drapes may be pulled off exposing unsterile parts contaminating the surgeon or the assistant or both often during manipulation of the arm This is avoided by using two segments of sterile stockinet closed at one end and long enough to cover the extremity from the finger tips to the middle of the upper arm First one layer and then the second is placed over the arm and fastened by a layer of sterile gauze bandage wrapped tightly around the arm

Anesthesia

Some of the simpler procedures may be performed under local anesthesia This is especially useful when the co-operation of the patient is needed Intravenous Pentothal Sodium when not contraindicated is a useful anesthetic agent It is easily administered and eliminates the difficulties caused by an anesthetist struggling to give inhalation anesthesia. For cases requiring more extensive surgery intratracheal anesthesia is by far the most desirable anesthesia and eliminates the usual difficulties encountered with routine inhalation anesthesia

Skin Incision

Vertical skin incisions produce wide ugly scars which are often the source of considerable mental distress—especially among women Unfortunately most extensive approaches to the shoulder joint region have an anterior vertical limb running parallel with the deltopectoral groove The smaller incisions generally used to remove calcareous deposits from the musculotendinous cuff also pursue a short vertical course This is not true of superior incisions which parallel the normal skin creases

Hitchcock has popularized a curved anterior skin incision which may be used instead of the anterior vertical incision This

FIG 332 Patient in sitting position for operative procedure in the region of the shoulder

FIG 334 Transacromial incision, with extension downward of the anterior limb of the incision This route gives the best cosmetic effect.

terminal branches of the anterior humeral circumflex artery Throughout its course it distributes vessels to the deltoid muscle and the shoulder joint

The anterior humeral circumflex artery arises from the axillary artery opposite the posterior It runs laterally directly beneath the coracobrachialis and the short head of the biceps brachii to reach the anterior aspect of the surgical neck of the humerus At the intertubercular groove it gives off an ascending branch which traverses the groove to supply the humeral head and the shoulder joint It proceeds thence around the neck of the humerus beneath the deltoid giving off ascending and descending branches and finally anastomosing with the posterior humeral circumflex artery

POSITION OF PATIENT

Correct positioning of the patient is essential to perform surgical procedures on the

FIG 333 (*Left*) A wide, ugly scar has formed following the exposure of the anterior region of the shoulder through a deltopectoral incision. (*Right*) Observe the cosmetic result in the two shoulders following the use of a curved incision on the right and an anterior vertical incision on the left side.

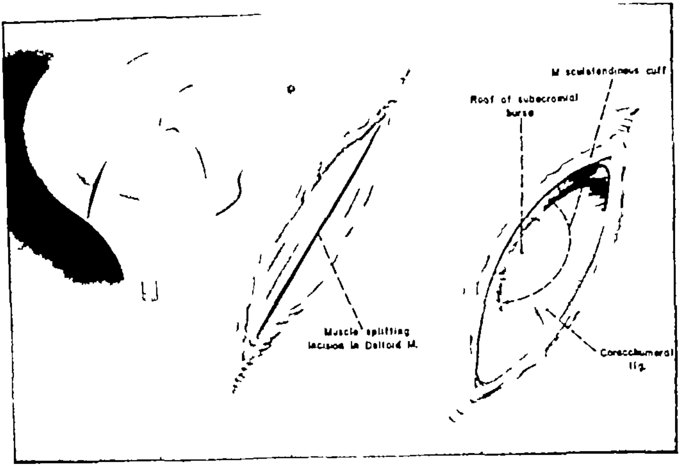

FIG 336 Bursal incision (*Left*) Skin incision. (*Center*) Line of separation of fibers of deltoid muscle. (*Right*) Exposure of subacromial bursa and musculotendinous cuff

humeral head The superior approaches af ford better exposure of these lesions The sitting position is preferred with the arm at the side and a small sandbag under the shoulder

A slightly curved skin incision is made along the border of the deltoid muscle be ginning at the lower border of the clavicle just to the inner side of the coracoid process and extending downward to a point just cephalad to the deltoid tuberosity of the humerus The adjacent borders of the del toid and the pectoralis major muscles form ing the deltopectoral cleft come into view The cephalic vein is seen transversing the cleft. To avoid injury to this vein a line of cleavage is developed in the anterior fibers of the deltoid approximately 1 centimeter from its anterior border This medial strip of muscle fibers together with the cephalic vein and the pectoralis major muscle, is re tracted medially and the deltoid laterally While splitting the deltoid muscle numer ous small veins and the deltoid branch of the thoraco-acromial artery are encoun tered These are ligated to ensure a bloodless field

The following structures are now visual ized The coracoid process to which are attached the pectoralis minor the coraco-brachialis and the short head of the biceps brachii muscles, the intertubercular sulcus, the long head of the biceps brachii muscle, the inner portion of the subacromial bursa and its subcoracoid extension and the ante-rior aspect of the greater tuberosity Ex ternal rotation of the extremity brings into view the tendon of the subscapularis muscle as it inserts into the lesser tuberosity Sep-aration of the long and the short heads of the biceps brachii exposes the tendons of the teres major and the latissimus dorsi muscles. The former inserts into the crest of the lesser tuberosity and the latter into the bottom of the intertubercular groove. The tendon of the teres major occupies a

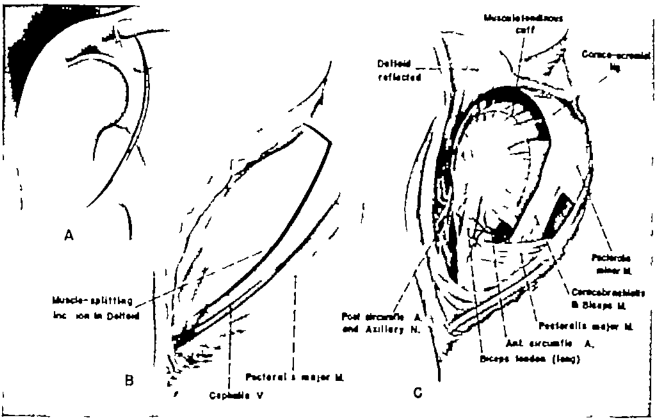

FIG 335 Deltopectoral incision (A) Skin incision. This may be replaced by an S-shaped incision. (B) Line of cleavage in anterior fibers of the deltoid muscle (C) Exposures of structures beneath the coracoacromial arch.

produces a better cosmetic result and mini mum scarring and helps to prevent the spreading of the incision In exposures utilizing both a horizontal and a vertical limb as the incision of Cubbins et al and Henry the writer substitutes the curved in cision of Hitchcock for the anterior limb (Figs 333 and 334)

APPROACHES TO SHOULDER JOINT REGIO\

ANTERIOR APPROACHES

All anterior incisions are designed to protect the axillary nerve from injury The course of the nerve must be constantly in the surgeon s mind while making one of these incisions. As already noted the axil lary nerve runs a horizontal course under cover of the deltoid about 2 to 2½ inches below the lateral margin of the acromion process On the skin surface this line lies slightly above a point midway between the tip of the acromion and the deltoid tuber osity on the humerus. Thus it is apparent that a "safety zone exists proximal to the course of the nerve and the deltoid fibers within this zone may be split without fear of injury to the nerve From a practical viewpoint an incision in this zone may ex tend from the margin of the acromion downward for 4 centimeters without traumatiz ing the nerve Beyond this as pointed out by McLaughlin the risk of inflicting damage to the nerve increases with each centi meter that the incision is extended downward Division of the nerve results in denervation of the mu_cle fibers anterior to the site of severance (Fig 328)

Approach through the Deltopectoral Cleft. This is a common approach to the anterior aspect of the shoulder region providing excellent exposure of lesions of the long head of the biceps brachii muscle and the bicipital groove It may be used for fracture and fracture-dislocations of the

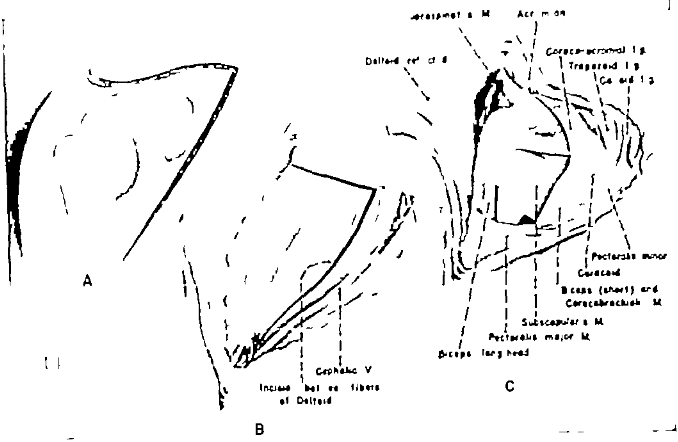

FIG 337 Anterosuperomedial approach of Thompson and Henry (A) Skin incision. If further exposure is desired the incision is continued around the acromion as in the incision of Cubbins et al (B) Line of reflection of split deltoid muscle from the clavicle by sharp dissection indicated (C) Exposure of structures in the anterior, superior and medial aspects of the shoulder region

zontal limb starts over the anterior surface of the acromioclavicular joint proceeds medially along the anterior surface of the outer third of the clavicle and joins the vertical limb at the deltopectoral sulcus just to the inner side of the coracoid process

Separation of the vertical limb s skin edges reveals the cephalic vein lying in the deltopectoral interval This vein together with a few anterior fibers of the deltoid and the *pectoralis major muscle is retracted* medially while the deltoid is retracted laterally Injury to the cephalic vein and the thoraco-acromial artery which lies in the upper end of the incision must be avoided while developing the vertical arm of the incision The clavicular head of the deltoid is separated from the outer third of the clavicle with a thin sharp osteotome The entire deltoid mass is then reflected downward and laterally giving an excellent view of the anterior and the lateral portions of the shoulder region (Fig 337)

Further exposure can be attained by severing the coraco-acromial ligament close to its attachment to the acromion dividing the tip of the coracoid process proximal to the insertion of the coracohumeral ligament, and displacing it downward and medially with its muscle attachments This step permits access to the anterior surface of the *subscapularis muscle and tendon* The anterior and the inferior portions of the fibrous capsule come into view if the tendon is divided an inch medial to its insertion into the lesser tuberosity and then displaced medially Longitudinal division of the capsule close to the glenoid brim permits exploration of the interior of the glenohumeral joint

Anterosuperoposterior Approach (Incision of Cubbins et al) If greater ex

position behind that of the latissimus dorsi The bilaminar tendon of the pectoralis major muscle can be seen inserting into the crest of the greater tuberosity Upon opening the roof of the subacromial bursa, its floor, which is adherent to the musculotendinous cuff is exposed (Fig 335)

Short Anterior Approach through the Deltoid Muscle. This approach to the subacromial region is most commonly employed for such minor surgical procedures as removal of calcareous deposits in the musculotendinous cuff excision of the subacromial bursa removal of osteophytes on the greater tuberosity and exploration The disadvantages of this approach are many It provides very poor exposure except for the structures immediately beneath the roof of the subacromial bursa the axillary nerve is very vulnerable to injury and finally it fails to provide enough room for reparative procedures on the musculotendinous cuff except for the most simple and very small tears

The sitting position is preferred for this approach The arm should be draped separately to facilitate free movements of the limb in any desired position Local anesthesia or Pentothal Sodium intravenously are the anesthetic agents of choice

Beginning at the acromioclavicular joint the skin incision is extended vertically downward for a distance not exceeding 2 inches The muscle fibers are split from above downward in line with the skin incision exposing the roof of the subacromial bursa Division of the bursal roof brings into view its floor and the outer surface of the musculotendinous cuff By external and internal rotation of the arm the entire insertion of the cuff can be visualized as well as the intertubercular sulcus the tendon of the long head of the biceps brachii muscle and the greater *and the lesser tuberosities* (Fig 336)

A lateral incision similarly gives access to the lateral and the superior aspects of the subacromial region Lateral incisions are necessary occasionally to reach calcareous deposits situated far posteriorly Exposure of the short muscle splitting incision can be increased by stripping subperiosteally an inch of the deltoid muscle on either side of the incision from its bony origin

The author has supplanted the short anterior vertical skin incision by a 2½ inch horizontal skin incision, placed an inch below the inferior border of the acromioclavicular joint The proximal 2 inches of the deltoid muscle are exposed by retracting the upper and lower margins As in the vertical incision, the deltoid muscle is split longitudinally in the line of its fibers for a distance of from 1½ to 2 inches This skin incision gives a better cosmetic result than the vertical incision Healing takes place with minimum scarring and separation of skin margins

Anterosuperomedial Approach (Incision of Thompson and Henry) This is a combination of Roberts approach to the acromioclavicular joint and the deltopectoral incision It provides excellent exposure of all the structures in the anterior and the superomedial aspects of the shoulder region This route practically eliminates danger to the axillary nerve Ample working room and good accessibility to the important structures are provided Lesions of the musculotendinous cuff and of the biceps tendon and fractures and fracture-dislocations of the head of the humerus can be cared for readily through this incision. However extensive reparative work on the musculotendinous cuff is performed best through the superior approaches The sitting position is preferable with the shoulder well over the side of the operating table and the arm draped separately Intratracheal anesthesia or Pentothal Sodium intravenously are superior to inhalation and local anesthesias

The vertical limb of the skin incision is *similar to that of the deltopectoral* approach It extends along the anterior border of the deltoid muscle beginning at the inferior margin of the clavicle at the junction of its outer and middle thirds and ending proximal to the deltoid tuberosity Its hori

the anterior border of the deltoid does not decrease the efficiency of the muscle This approach is particularly indicated in reconstruction procedures of the musculotendinous cuff McLaughlin points out that it facilitates removal of displaced fractured fragments of the humeral head from above rather than pulling them through the brachial plexus from below Reattachment of the labrum or capsule to the glenoid rim for recurrent dislocations of the shoulder is performed readily from within the scapulohumeral joint The Nicola procedure also can be performed with greater accuracy because the tunnel for the biceps tendon is made from above downward and the point of exit of the tendon from the head of the humerus is chosen under vision Finally, this route enables better restoration of fractured fragments to their normal anatomic position

The position of choice is with the patient seated and the shoulder extending well beyond the edge of the operating table A sandbag is placed under the shoulder, and the table is tilted away from the operator The arm is draped separately to facilitate movement of the limb in any desired position. Intratracheal anesthesia is preferred

Beginning at the posterior border of the acromion and lateral to the acromioclavicular joint the skin incision is carried across the top of the shoulder to a point 3 to 5 centimeters in front of the anterior border of the acromion The incision is developed anteriorly through the deltoid muscle exposing the roof of the subacromial bursa and the coraco-acromial ligament Incision of the superior bursal wall brings into view the greater portion of the outer surface of the musculotendinous cuff only the most posterior and inferior portions remaining obscured

Next the superior limb of the incision is deepened to the bone and the acromion is divided with a thin blade osteotome For simple repair of the musculotendinous cuff, an oblique osteotomy is done beginning midway between the acromioclavicular joint and the lateral border of the acromion and directed laterally to emerge at the lateral tip of the acromion In cases requiring more extensive surgery and exploration of the interior of the glenohumeral joint the osteotomy is directed anteroposteriorly By reflecting the deltoid and the outer fragment of the acromion laterally all the superior and lateral aspects of the shoulder region are visualized as far as the surgical neck

Access to the interior of the joint is achieved by a longitudinal incision in the musculotendinous cuff in the interval between the subscapularis and the supraspinatus muscles and parallel with the fibers of the coracohumeral ligament There is no need to replace the detached fragment of the acromion process it is more advantageous to dissect it free and discard it By reducing the size of the overhanging acromion, impingement of the greater tuberosity or the repaired cuff against the acromion is less likely to occur upon elevation of the extremity McLaughlin emphasizes that a small acromion means a less prominent fulcrum, over which the humeral head may be levered out of the glenoid cavity Hence, the tendency for recurrences is minimized in operative procedures for recurrent dislocations Moreover the postoperative course is less painful, and rehabilitation of the patient is quicker when the detached fragment is removed

Saber-cut Incision (Codman) This incision, first described by Codman, provides an excellent exposure of the subacromial bursa and the whole musculotendinous cuff It also brings into view the extra-articular portion of the tendon of the long head of the biceps brachii muscle All regions of the inside of the joint can be explored by opening the capsule of the joint in the same manner as described in the transacromial approach. However, it is a mutilating incision and possesses no advantages over the transacromial route

Beginning from 3 to 4 centimeters below the spine of the scapula the skin incision proceeds anteriorly over the top of the

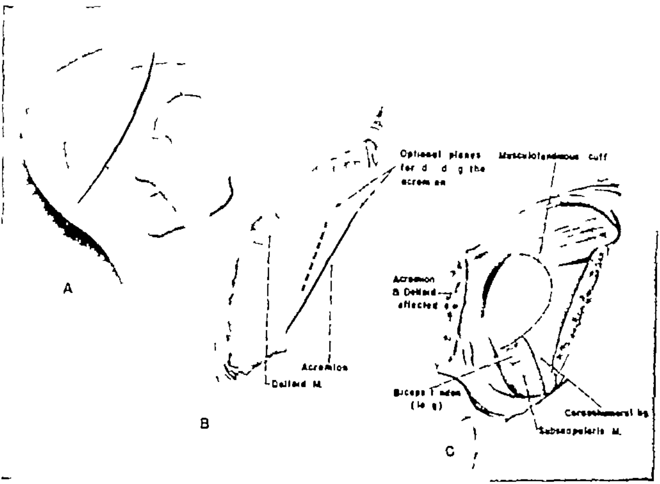

FIG 338 Transacromial incision (McLaughlin) (A) Skin incision (B) Planes through which acromion may be divided to gain access to the subacromial region (C) Structures exposed after the deltoid is reflected downward and outward.

posure of the lateral or exposure of the posterior aspect of the shoulder region is desired the horizontal arm of the antero-superomedial incision is projected around the acromion process and along the lateral half of the spine of the scapula (Fig 337A) By sharp dissection with a thin osteotome the origin of the deltoid is stripped from the anterior border of the clavicle the acromion process and the spine of the scapula Downward reflection of the entire deltoid permits complete visualization of the anterior lateral and posterior shoulder regions By dividing longitudinally the posterior portion of the musculotendinous cuff proximal to its insertion into the greater tuberosity the interior of the glenohumeral joint can be inspected

The last two approaches are particularly useful for fractures, fracture-dislocations arthrodesis of the glenohumeral joint, repair of tears of the musculotendinous cuff, recurrent dislocation of the scapulohumeral joint lesions of the long head of the biceps brachii muscle and tumors of the upper end of the humerus Giant-cell tumors and cysts of upper end of the humerus are made readily accessible by these routes

SUPERIOR APPROACHES

Transacromial Approach (McLaughlin) This is the most commonly used superior approach providing adequate exposure of the entire superior shoulder region Since the skin incision parallels the skin creases there is little spreading of the scar hence the cosmetic result is good. Injury to the axillary nerve is not likely to occur if all muscle splitting is done from above downward starting at the anterior margin of the acromion.

Moreover separation of muscle fibers near

the superior approaches) with the arm draped separately and the operating table tilted away from the surgeon Intratracheal anesthesia is preferred

Beginning at the acromioclavicular joint the skin incision proceeds posteriorly over the top of the acromion to the spine of the scapula then gently curves downward and outward to a point about 4 centimeters above the posterior fold of the axilla Next the posterior border of the deltoid muscle is identified and the interval between the deltoid and the deeper muscles is developed by blunt dissection The deltoid is divided 1 centimeter from its scapular origin and detached subperiosteally as far as the acromioclavicular joint By retracting the detached portion of the muscle laterally the posterior aspect of the joint is brought into view Care must be exercised at this point to avoid injury to the axillary nerve and its branches and to the posterior axillary artery as they emerge from the quadilateral space which can now be observed readily

Some surgeons prefer to divide the lateral half of the acromion and to displace it

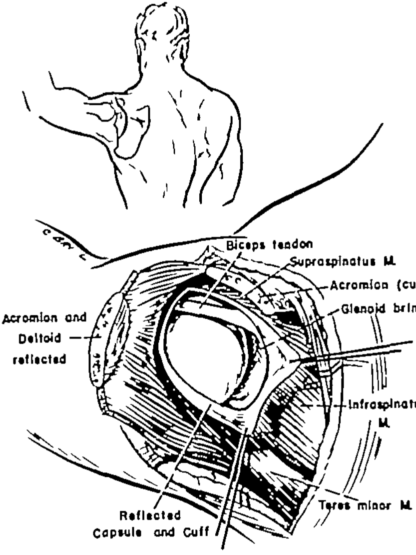

FIG 339 Kocher's posterior route to the scapulohumeral joint Mobilization of the posterior portion of the deltoid muscle may be achieved either by subperiosteal detachment from the spine and osteotomy of the outer end of the acromion or by continuing the subperiosteal detachment from the spine around the acromion as far as the acromioclavicular joint.

shoulder in line with the acromioclavicular joint and ends roughly from 3 to 4 centimeters below the border of the acromion process Anteriorly and posteriorly the incision is deepened through the fibers of the deltoid muscle At this point care must be exercised to avoid damage to the axillary nerve in front and behind

The acromioclavicular ligaments are severed and the acromion is divided in a line directed anteroposteriorly with a thin osteotome The detached acromion, together with the deltoid muscle is retracted downward bringing into view the subacromial bursa the musculotendinous cuff the intertubercular sulcus and the long head of the biceps tendon

The topographic anatomy of the suprascapular nerve and artery must be kept in mind while displacing the deltoid mass downward Forceful retraction may inflict severe injury to these structures as they traverse the suprascapular notch On closure of the incision the detached acromion process is sutured or wired to its normal anatomic position and the divided edges of the superior acromioclavicular ligament are approximated by interrupted sutures

Superior Approach of Henry This route provides excellent exposure of the superior anterior lateral and posterior aspects of the shoulder region without severing the acromion process Minor cuff tears can be repaired readily the lesions of the tendon of the long head of the biceps brachii can be dealt with fracture fragments reassembled fracture-dislocations reduced and operations for recurrent dislocation of the shoulder performed However as previously stated the transacromial approach gives more adequate exposure for all the afore-mentioned surgical procedures and is particularly desirable in repairing extensive tears of the musculotendinous cuff The position of the patient and preferred anesthesia are similar to those of other superior approaches

Essentially the skin incision is a continuation of the deltopectoral incision over the top of the shoulder to a point just below the spine of the scapula As in the deltopectoral approach the interval between the deltoid and the pectoralis major muscle is developed to the lower margin of the clavicle The cephalic vein with 1 centimeter of the anterior border of the deltoid together with the pectoralis major, is retracted medially and the deltoid muscle is retracted laterally By sharp dissection with a thin osteotome the origin of the deltoid is stripped from the anterior border of the outer one-third of the clavicle and the lateral edge of the acromion The deltoid muscle is then retracted downward and outward If more exposure is desired, the origin of the deltoid may be detached from the entire acromion and lateral one third of the spine of the scapula.

Posterior Approaches

As noted above the posterior aspect of the shoulder region may be visualized through the superior routes or by extension of the anterosuperomedial incisions around the lateral and the posterior margins of the acromion and the lateral portion of the spine of the scapula (Cubbin s incision) However it is sometimes desirable to limit exposure to the posterior aspect of the shoulder making superior approaches and Cubbin s incision not justified

The most commonly used posterior route is the one of Kocher Several others have been described (the approaches of Bennett, Harmon and of Rowe and Yee) but they possess no particular features which would make them superior to the Kocher approach. Yee and Rowe emphasize the value of their approach to the postero-inferior aspect of the glenohumeral joint along anatomic planes with little risk of injury to the axillary veins and branches supplying the deltoid and the teres minor muscles

Posterior Approach of Kocher The patient may be placed face down with a sandbag under the shoulder, the head turned to the opposite side, and the outstretched arm supported on an arm board or in the sitting position (as described for

the superior approaches) with the arm draped separately and the operating table tilted away from the surgeon Intratracheal anesthesia is preferred

Beginning at the acromioclavicular joint the skin incision proceeds posteriorly over the top of the acromion to the spine of the scapula then gently curves downward and outward to a point about 4 centimeters above the posterior fold of the axilla Next the posterior border of the deltoid muscle is identified and the interval between the deltoid and the deeper muscles is developed by blunt dissection The deltoid is divided 1 centimeter from its scapular origin and detached subperiosteally as far as the acromioclavicular joint By retracting the detached portion of the muscle laterally the posterior aspect of the joint is brought into view Care must be exercised at this point to avoid injury to the axillary nerve and its branches and to the posterior axillary artery as they emerge from the quadilateral space which can now be observed readily

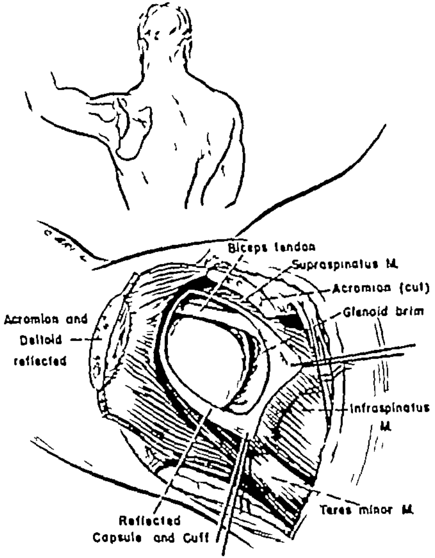

FIG 339 Kocher s posterior route to the scapulohumeral joint Mobilization of the posterior portion of the deltoid muscle may be achieved either by subperiosteal detachment from the spine and osteotomy of the outer end of the acromion or by continuing the subperiosteal detachment from the spine around the acromion as far as the acromioclavicular joint.

Some surgeons prefer to divide the lateral half of the acromion and to displace it

laterally with the attached deltoid instead of stripping the deltoid as far as the acromioclavicular joint If a view of the posterior aspect of the interior of the glenohumeral joint is desired, the tendons of the infraspinatus the teres minor and a portion of the tendon of the supraspinatus muscles may be divided longitudinally, together with the capsule close to their insertion into the greater tuberosity leaving sufficient tissue for easy reattachment of the severed ends The intracapsular portion of the tendon of the long head of the biceps brachii muscle must not be cut in this last step of the procedure (Fig. 339)

Posterior Approach of Rowe and Yee The patient is placed in the prone position with both arms abducted and supported on arm boards A large sandbag or small pillow is placed under the shoulder to be exposed and the patient s head is turned to the opposite side Intratracheal anesthesia is far superior to any of the inhalation anesthesias.

Beginning at the junction of the middle and the inner thirds of the spine of the scapula the skin incision is continued along the spine The incision then curves gently downward over the posterior aspect of the shoulder joint for approximately 4 inches By retracting the skin medially the scapular origin of the deltoid is visualized This is then stripped subperiosteally from the spine of the scapula The deltoid is split downward for approximately 3 inches about 1½ inches from its medial border The lateral triangular muscle flap thus formed is retracted laterally exposing the infraspinatus and the teres minor muscles The interval between these two muscles is developed by blunt dissection and the infraspinatus is similarly separated from the underlying fibrous capsule The tendon of the infraspinatus muscle is divided ½ inch from its insertion into the great tuberosity and retracted medially Retraction of the teres minor downward now brings into view the entire posterior and inferior portions of the capsule Care must be exercised to limit the vertical incision severing the infraspinatus tendon to the upper border of the teres minor muscle Should it extend beyond this point the axillary nerve traversing the quadrilateral space may be injured (Fig 340)

A vertical incision in the capsule permits adequate exploration of the inside of the posterior and the inferior aspects of the joint Through this route Rowe and Yee reattached the torn labrum to the posterior lip of the glenoid brim in two cases of recurrent posterior dislocation of the shoulder in the same manner that Bankart reattaches the anterior labrum to the anterior glenoid brim for recurrent anterior dislocations

Approach to the Sternoclavicular Joint

The skin incision begins over the clavicular head of the sternocleidomastoid muscle, just above the upper border of the clavicle and extends medially to the outer border of the sternal head It then curves gently downward on the anterior surface of the sternum for 1½ inches Retraction of the skin margins exposes the tendinous insertions of both heads of the sternocleidomastoid muscle. By sharp subperiosteal dissection the sternocleidomastoid and the pectoralis major muscles are reflected from the clavicle upward and downward respectively thereby exposing the fibrous capsule of the sternoclavicular joint A horizontal or curved incision is made in the articular capsule exposing adequately the interior of the joint.

Approach to the Acromioclavicular Joint (Infraclavicular Route of Cubbins et al)

The skin incision begins at the angle of the acromion proceeds medially along the lower border of the acromion the acromioclavicular joint and the outer third of the clavicle to the deltopectoral cleft where it swings downward and outward for a distance of from 1 to 2 inches following the anterior border of the deltoid Next the interval between the deltoid and the pec

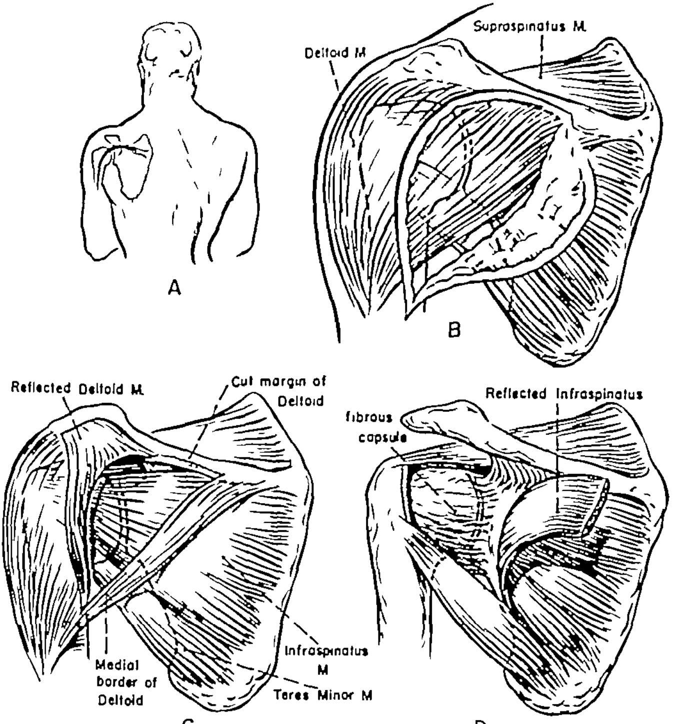

FIG 340 Posterior approach (Rowe and Yee) (A) Skin incision. (B) Medial reflection of skin exposing posterior portion of deltoid (C) Deltoid split longitudinally 1 and ½ inches from its medial border and detached subperiosteally from the spine then retracted laterally (D) Infraspinatus tendon is severed ½ inch from its insertion into the greater tuberosity and retracted medially exposing the posterior portion of the fibrous capsule

toralis major muscles is developed to the clavicle

At this point care must be taken not to injure the cephalic vein The origin of the deltoid is stripped by sharp subperiosteal dissection from the anterior margin of the clavicle and the acromion and reflected downward In a similar manner the trapezius is stripped from the superior surface of the clavicle and the acromion and retracted upward The pectoralis major, together with the cephalic vein and 1 centi

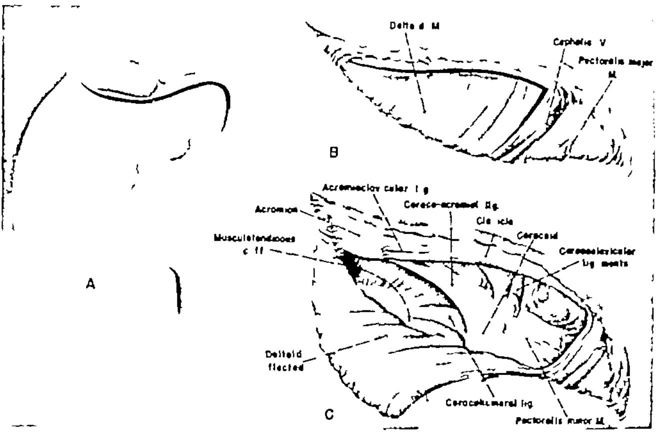

FIG 341 Infraclavicular approach to the acromioclavicular joint (Cubbins et al.) (A) Skin incision (B) Line of subperiosteal stripping of the origin of deltoid muscle from the clavicle (C) Exposure of the acromioclavicular joint and coracoclavicular ligaments

meter of the anterior border of the deltoid is retracted mesially and downward Hence the coracoid process the coraco-acromial ligament the coracoclavicular ligaments (trapezoid and conoid ligaments) and the articular capsule of the acromioclavicular joint are exposed (Fig 341)

Incision to Expose the Clavicle

The patient lies supine with a small sand bag or a folded sheet between the shoulder blades the head is turned to the opposite side

The clavicle lies for its entire length in a very superficial position It can be palpated readily beneath the skin from its acromial to its sternal end Exposure of this bone is achieved best by an incision in the supra clavicular fossa running along the antero-superior border of the clavicle from the sternal to the acromial end The skin inci sion is carried through the platysma muscle and the periosteum down to the bone By sharp dissection with a thin blade osteotome the periosteum and attached clavicu lar head of the sternocleidomastoid muscle and the trapezius muscle are stripped from the shaft and retracted proximally in a like manner the pectoralis major and the deltoid muscles are stripped from the clav icle and reflected distally

Incisions to Expose the Scapula

Occasionally it becomes necessary to ex pose part of or all the scapula Benign lesions such as osteochondromas which re-quire excision are encountered occasionally on the ventral or dorsal surface of the scapula

Scapulectomy may be indicated for some malignant bone lesions Profuse bleeding can be prevented by sharp subperiosteal stripping of the overlying muscles from either surface of the scapula.

Exposure of Vertebral Border of Scapula

The patient is prone with a flat sandbag under the shoulder on the side of the opera

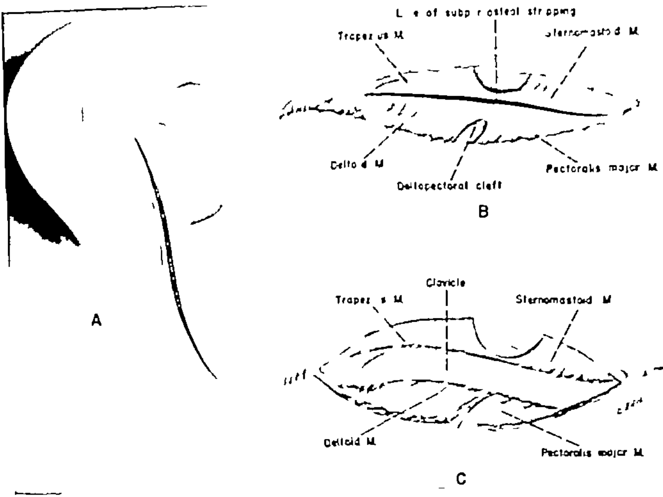

FIG 342 Exposure of entire clavicle

tion and the arm is draped separately to the side Intratracheal anesthesia facilitates the operative procedure

The skin incision begins at the superior angle of the scapula continues distally along its vertebral border and ends at the inferior angle Next the periosteum is incised horizontally over the root of the spine of the scapula, beginning at its vertebral margin for a distance of 2 inches The periosteum and the attached trapezius are stripped from the spine with a sharp osteotome the incision is continued upward and medially through the substance of the trapezius muscle in the line of its fibers for 1 inch A triangular flap of muscle is thus formed which when reflected upward and medially exposes the muscles inserting into the vertebral border of the scapula

The above mentioned muscles the levator scapulae the rhomboid minor the rhomboid major the supraspinatus, the infraspinatus the teres major and the teres minor are incised to the bone close to the vertebral border and then detached subperiosteally with a sharp osteotome exposing the vertebral margin of the scapula Subperiosteal stripping and reflection of the muscles may be extended on the dorsal surface of the scapula as far laterally as desired If the ventral surface of the scapula must be exposed the subperiosteal stripping is carried around the vertebral border to the ventral aspect and the muscles attached to the undersurface of the scapula are stripped away (Fig 343)

Kocher Incision. Exposure of the entire scapula may be achieved by Kocher s incision The vertical limb of the incision begins at the superior angle, continues along the vertebral border and ends at the inferior angle of the scapula the horizontal limb runs along the superior surface of the spine of the scapula beginning at the vertebral border and ending at the lateral margin of the acromion The horizontal incision is

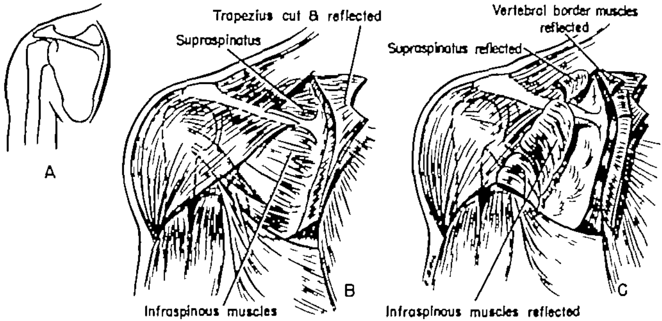

FIG 343 Exposure of the vertebral border of scapula.

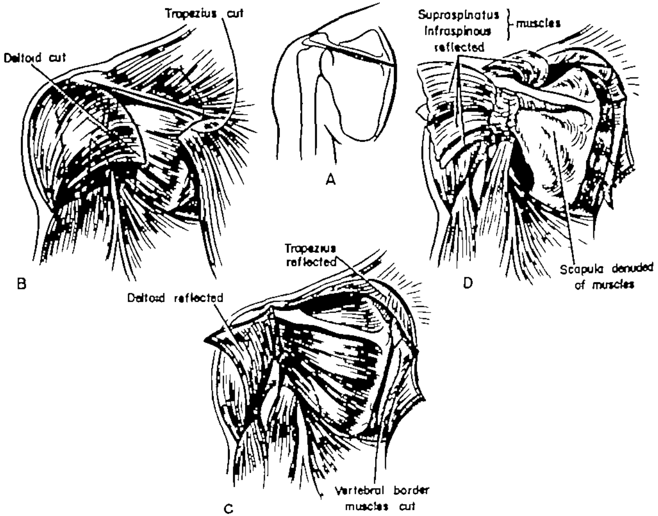

FIG 344 Exposure of entire scapula (Kocher)

deepened through the periosteum of the spine to the bone and continues medially through the substance of the trapezius muscle for 2 to 3 centimeters

The periosteum and the attached trapezius muscle are detached from the spine and reflected upward by sharp subperiosteal dissection In a similar manner, the deltoid is detached and reflected downward and laterally All muscles are divided close to their line of attachment to the entire vertebral border and stripped away subperiosteally By reflecting the muscle masses on the ventral and dorsal surfaces the whole of the scapula may be exposed (Fig 344)

ARTHRODESIS OF THE SCAPULOHUMERAL JOINT

General Considerations

There are few indications for arthrodesis of the scapulohumeral joint However, when *justified and properly performed* the procedure gives gratifying results.

It is performed for the following conditions

1 Paralysis of the deltoid muscle resulting from anterior poliomyelitis

2 Paralysis of the deltoid secondary to peripheral nerve (axillary nerve) or brachial plexus injury

3 Traumatic lesions of the upper end of the humerus

4 Complete or massive avulsion of the musculotendinous cuff in which some type of repair is not possible

5 Tuberculosis of the scapulohumeral joint

6 Neurotrophic disorders (syphilis)

7 Infectious arthritis associated with destruction of the joint and pain

Paralysis of the deltoid muscle and tuberculosis of the glenohumeral joint are the most common of the aforementioned indications One is rarely justified in fusing the shoulder joint for traumatic disorders As has been pointed out (Chap 8) malalignment of fractured fragments except in extreme cases, does not preclude good painless shoulder function In fracture-dislocation with complete separation of the humeral head from the shaft, the head may be removed and the cuff may be attached to the rounded end of the shaft Such procedure gives a result superior to fusion of the shoulder joint Moreover, such lesions usually occur in the late decades of life, when an arthrodesing procedure and the subsequent rehabilitation of the extremity may prove to be too formidable

Some workers prescribe arthrodesis in cases of massive or complete avulsion of the musculotendinous cuff, believing that reattachment of the cuff results in a less useful extremity However this has not been the experience of the author who agrees with McLaughlin that reattachment of the cuff to some point on the head of the humerus can be achieved in most of these cases and that the results attained are more desirable than those of joint fusion (see Chap 4)

Arthrodesis is the treatment of choice for tuberculosis of the scapulohumeral joint. Only complete obliteration of the joint can assure eradication of the disease However, it never should be performed during the active stages A course of streptomycin before and after the procedure minimizes the possibility of secondary infection and sinus formation and favors the healing of affected tissues Arthrodesis should be withheld in children until sufficient growth of the humeral head and the scapula has occurred The operation is rarely justifiable before the age of 6 years

Adequate evaluation of the musculature of the entire upper extremity is imperative before fusion in cases with paralysis of the deltoid muscle Good power in the serratus anticus and the trapezius muscles is a prime requisite if arthrodesis is contemplated, since these muscles will be responsible for motivating the shoulder girdle following the fusion Moreover it must be pointed out again that the chief function of the shoulder girdle is to place the hand in positions for function where it can perform required

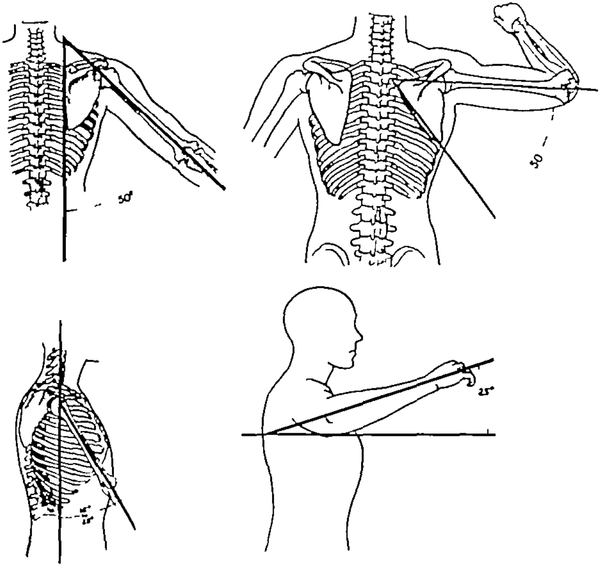

FIG 345 (*Top left*) The recommended position of abduction with the scapula in normal anatomic position the humerus is abducted 50 degrees from the vertebral border of the scapula (viewed from behind) (*Top right*) Recommended position of immobilization of the arm after arthrodesis Observe the relation of the humerus to the scapula and to the trunk. (*Bottom left*) Recommended amount of flexion with scapula in normal anatomic position. (*Bottom right*) Side view exhibiting recommended positions of flexion and rotation (Research Committee of the American Orthopedic Association J Bone & Joint Surg 24 704 705 and 706)

duties. If paralysis of the hand exists arthrodesis of the scapulohumeral joint (to permit the patient to place the hand in various positions of function through the medium of scapular motion) is a needless operation unless done to provide a sense of stability

It must be appreciated that arthrodesis of the glenohumeral joint is not a simple procedure and that the results are often far from satisfactory Several factors are responsible The architectural structure of the bony joint components does not lend itself readily to surgical fusion the glenoid cavity is small It provides only a meager surface of cancellous bone when denuded of its cartilage and only a small portion of the large spherical head is in direct contact with the glenoid cavity The overhanging acromion is at a considerable distance from the head of the humerus when the latter is in its normal anatomic relation to the glenoid fossa Lack of knowledge or dis-

regard of the correct position of the humerus in relation to the vertebral border of the scapula (necessary for optimum function) and such inadequate postoperative management as improperly applied casts and short periods of immobilization are also responsible for unsatisfactory shoulder fusions

In 1942 the Research Committee of the American Orthopedic Association conducted a study on 145 cases of infantile paralysis Of this group an arthrodesis of one shoulder had been performed on 100 a bilateral arthrodesis in 1 case some type of muscle transplanation in 43 stabilization of a subluxated shoulder by the Nicola operation for 2 and stabilization of the shoulders by tying the scapulae together with a fascial sling for 1

This investigation permitted formulation of the following pertinent conclusions the most common causes leading to poor function were poor positioning of the humerus in relation to the scapula postoperatively and disregard of the position of rotation of the humerus

Younger individuals developed better scapular movements than older individuals Scapular winging did not occur with the shoulder fused in 45° abduction in the presence of good power in the muscles controlling the scapula (upper trapezius and serratus anterior muscles) abduction was possible to 90° and the arm came readily to the side Slightly greater abduction improved the functional result but not the cosmetic effect. In view of these findings boys under 12 years of age should be fused in 55° abduction This results in slight winging of the scapula but gives a more useful range of scapular motion Girls should be fused in 45° abduction because this position gives the optimum cosmetic result.

Optimum function depends upon good power in the upper portion of the trapezius and the upper two-thirds of the serratus anterior muscles The upper fibers of the trapezius muscle raise the acromion process and the entire shoulder girdle pivots on the sternoclavicular joint The trapezius muscle is able to perform the above function even in the absence of power in the serratus anterior but it can abduct the arm only 45 It was also noted that when the humerus was fused at 45° or over from the vertebral border of the scapula in the absence of power in the serratus anterior the weight of the arm may rotate and depress the outer portion of the scapula thereby stretching and reducing the efficiency of the trapezius It becomes apparent that with a paralyzed serratus anterior the optimum position of abduction of the humerus from the scapula is 30°

Fusion of the shoulder is justified with only fair power in the trapezius and paralysis of all other muscles because some functional improvement is always achieved. Also a flail shoulder usually rides at a higher level than the normal shoulder and arthdrodesis restores the normal alignment thereby improving the cosmetic effect.

Adduction contractures of the soft tissues about the scapulohumeral joint (resulting from the extremity s being in an extreme adducted position close to the chest wall for long intervals) may preclude positioning of the humerus in the desired degrees of abduction unless the tissues are first released or stretched

True abduction at operation is determined by the angle that the humerus makes with the vertebral border of the scapula. Having attained the true abduction angle desired the scapula and the humerus can be elevated further as a single unit so that the arm is abducted 70° to 90° from the trunk. This position favors relaxation of the trapezius and the serratus anterior muscles However due to the tendency of the scapula to rotate within the plaster cast this relationship may be difficult to maintain or even lost Internal fixation between the head of the humerus and the neck of the scapula or between the acromium process and the head is advocated to ensure maintenance of the desired abduction angle

Care should be exercised to avoid excessive flexion of the humerus in relation to the

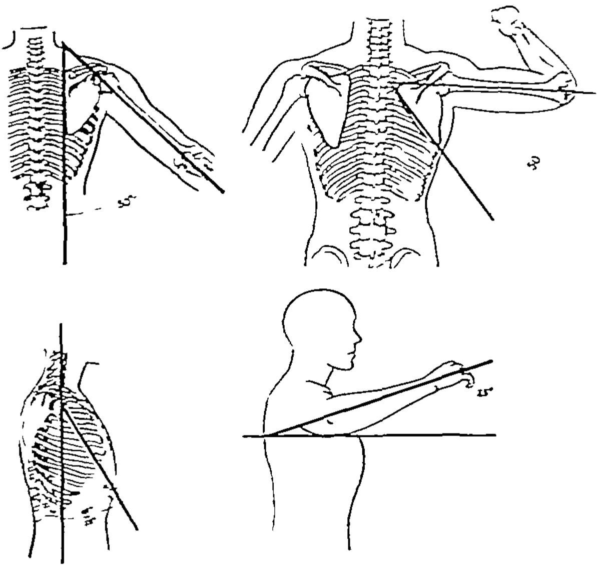

Fig. 54 (*Top left*) The recommended position of abduction with the scapula in normal anatomic position, the humerus is abducted 50 degrees from the vertebral border of the scapula (viewed from behind). (*Top right*) Recommended position of immobilization of the arm after arthrodesis. Observe the relation of the humerus to the scapula and to the trunk. (*Bottom left*) Recommended amount of flexion with scapula in normal anatomic position. (*Bottom right*) Side view exhibiting recommended positions of flexion and rotation. (Research Committee of the American Orthopedic Association J Bone & Joint Surg. 24 704, 705 and 706.)

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True abduction at operation is determined by the angle that the humerus makes with the vertebral border of the scapula Having attained the true abduction angle desired the scapula and the humerus can be elevated further as a single unit so that the arm is abducted 70 to 90° from the trunk This position favors relaxation of the trapezius and the serratus anterior muscles However due to the tendency of the scapula to rotate within the plaster cast this relationship may be difficult to maintain or even lost Internal fixation between the head of the humerus and the neck of the scapula or between the acromium process and the head is advocated to ensure maintenance of the desired abduction angle

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scapula, a position which causes winging of the scapula and stretching of the serratus anterior muscle The optimum position of flexion in girls is from 10° to 15° such a position permits the arm to be flat against the trunk. In boys, flexion of 25° increases the usefulness of the extremity but sacrifices slightly the cosmetic effect. As a rule, an arm placed in from 70° to 90° abduction and from 35° to 40° flexion following operation results in the desired flexion of the humerus to the vertebral border of the scapula Some degree of flexion is essential for good performance of the shoulder girdle Without it, the arm is in a useless position

Poor function results from excessive internal or external rotation of the humerus in the abducted position Excessive external rotation is worse than excessive internal rotation Fifteen degrees internal rotation without abducting the arm beyond 35° or 40° permits the hand to reach the top of the head. For most cases, the optimum position of function is from 45 to 55° abduction of the humerus from the vertebral border of the scapula from 70 to 90° of abduction of the arm from the trunk from 15° to 25 forward flexion of the arm from the scapula and from 25° to 30 upward tilt of the flexed forearm above the horizontal plane (Fig 345)

If a weak elbow and hand exist on the opposite side, the optimum position of function of the fused shoulder is in greater internal rotation but not exceeding 45°

No evidence was uncovered which pointed to deleterious effect on scoliosis by shoulder arthrodesis However scapular movements are restricted by scoliosis If scoliosis is present with the convexity toward the affected side and the shoulder is fused in too much flexion, excessive winging results and the deformity becomes more obvious

Function is better in individuals whose shoulders are fused before the age of 12 years Fusion may be done as early as 6 years of age. Disturbance of growth does not generally occur in young children following arthrodesis. In cases requiring bilateral shoulder fusion, the position should permit the hands to be brought together The weaker side should be fused in more internal rotation when the muscle power differs in the two shoulders. If the muscle power is the same, in right handed individuals the left is placed in a position of greater internal rotation in left handed individuals, the right is fused in a position of greater internal rotation

Arthrodesis is justified in completely flail extremities The advantages cited were ease of turning in bed getting into a coat with greater ease the ability to use the hand to steady a piece of paper while writing and a sense of stability in the shoulder girdle. The optimum position of function in individuals with flail or weak elbows is only slight abduction of the humerus from the scapula and from 40° to 45° of internal rotation In many instances arthrodesis of the shoulder increases the flexion power of the elbow

The desired relationship of the humerus to the scapula may be lost in plaster cast Improved function occurs in arthdrodesis regardless of the method employed when the arm is placed in the correct position of function and adequate postoperative management is provided The committee recommends that some type of internal fixation be used to maintain the desired position.

Age (under 10 years) is not a significant factor in failure of fusion rather, short periods of immobilization are more likely to result in nonunion Three months should be the minimum period of fixation. Immobilization should be continued for 2 more months if bony union is not achieved at the end of this period Regardless of the presence of a bony fusion or a fibrous ankylosis the glenohumeral joint is stabilized permanently in a fixed position after five months. Hence plaster or any other type of fixation is not indicated 5 months postoperatively After bony union is demonstrable roentgenographically no further change occurs in the humeroscapular angle although from 10 to 20 of abduction may be lost in the first

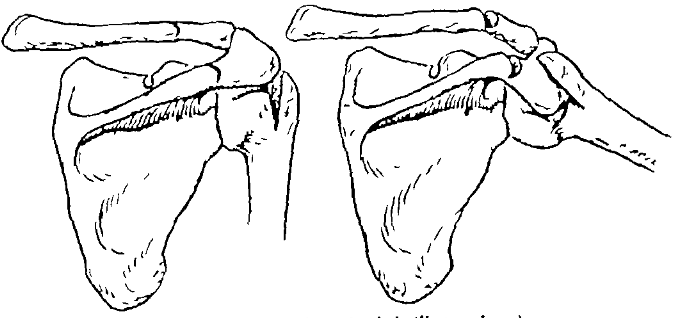


Fig 346 Extra articular arthrodesis (Watson Jones)

5 months Fibrous ankylosis is undesirable because pain and fatigue may occur Moreover most of these cases disclose only slight *abduction a position which permits poor* scapular motion

Arthrodesing Procedures

Numerous operations have been described for achieving *arthrodesis of the gleno-*humeral joint. Essentially the operations fall into three categories extra articular arthrodesis intra articular arthrodesis and a combination of both methods

*Extra articular arthrodesis is the pro-*cedure of choice in tuberculosis of the glenohumeral joint The combined procedure may be employed in nontuberculous cases Intra articular arthrodesis alone results in a high percentage of failures The author has found that by utilizing the principle of compression solid bony ankylosis of the joint is obtained in a considerably shorter period than when compression was not employed Moreover, osseous union occurred in all instances in which compression was added to the procedure

Extra articular Arthrodesis. The two most commonly used methods are the Watson Jones and the Putti technics

Extra articular Arthrodesis of Watson Jones This procedure is more easily *performed with the patient in a sitting posi*tion with the shoulder well over the side of the table and the arm draped separately to be manipulated readily in any direction

A lateral skin incision is made beginning on the top of the shoulder 3 inches above and ending 3 inches below the acromioclavicular joint The incision is deepened from above downward through the deltoid muscle parallel with its fibers If care is exercised not to split the deltoid more than 4 centimeters from the lateral margin of *the acromion the axillary nerve will not be* severed The origin of the deltoid is then reflected from the acromion the spine of the scapula and the clavicle by sharp dissection with a thin blade osteotome Next the acromion on its superior and inferior surfaces and the lateral third of the clavicle are denuded to cancellous bone

Just distal to the line of insertion of the musculotendinous cuff into the greater tu*berosity*, a bone flap (measuring 1 inch in width and 2 inches in length) is elevated outward from the anterolateral aspect of the humerus with a wide osteotome An incomplete osteotomy is made in the outer third of the clavicle and the root of the acromion The acromion and the distal end of the clav

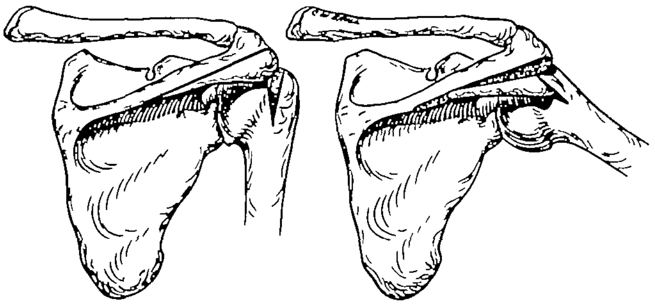


FIG 347 Extra articular arthrodesis (Putti)

icle are then forced downward, so that they engage beneath the bone flap elevated from the humerus when the humerus is abducted (Fig 346)

EXTRA ARTICULAR ARTHRODESIS OF PUTTI The patient is placed on the unaffected side and the arm is draped independently permitting free manipulation of the extremity A long skin incision is made along the entire length of the spine of the scapula and continued downward on the lateral aspect of the arm. By sharp subperiosteal dissection all soft tissues are stripped from the spine for its entire length and from the acromion process Next the spine is detached from its base by a thin osteotome beginning at its vertebral end and proceeding toward the acromion The acromion is divided longitudinally into medial and lateral segments the medial segment remains attached to the scapula, while the lateral is continuous with the spine of the scapula. The upper end of the humerus is exposed by splitting the deltoid fibers from above downward

Some workers sacrifice the axillary nerve and the posterior humeral circumflex artery in this step However this can be avoided by staying in the safety zone below the acromion. Severance of the nerve following arthrodesis of the glenohumeral joint is of no great significance because the shoulder girdle will now be motivated by the trapezius and the serratus anterior muscles (the deltoid no longer playing a role in movements of the arm) Nevertheless it is poor surgical technic to divide a healthy nerve unless it is absolutely necessary A bone flap is now elevated outward from the lateral surface of the humerus and the bone transplant comprising the acromion and the spine is wedged beneath it so that the acromion fits tightly under the osseous flap With the arm abducted the transplant is anchored by a stout chromic suture to the raw surface of the medial portion of the acromion (Fig 347)

Intra articular Arthrodesis (Steindler) Most so-called intra-articular procedures are really combined intra-articular and extra articular operations Steindler's technic however is truly an intra articular arthrodesis The superior aspect of the glenohumeral joint is exposed through a semicircular incision around and beneath the acromion The medial flap is reflected from the superior surface of the acromion for an inch Next the central origin of the deltoid muscle and its acromial attachment is identified and the acromion is divided from ½ to ¾ inches from its lateral margin with a thin osteotome The detached acromion with the deltoid is reflexed downward thus exposing the subacromial bursa and the musculotendinous cuff A longi

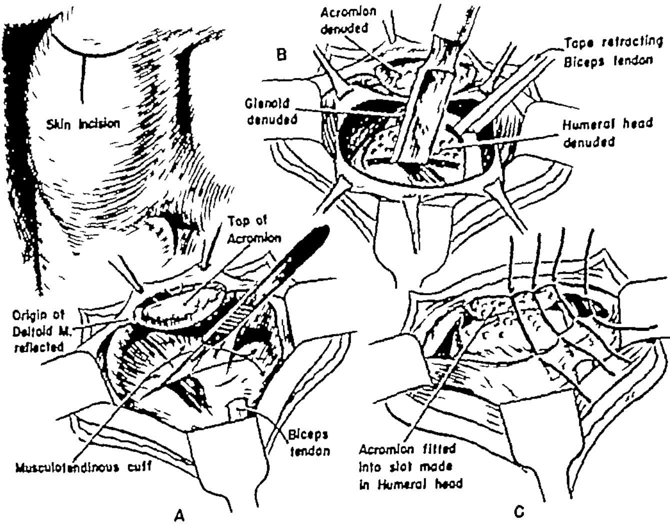


Fig 348 Combined intra articular and extra articular arthrodesis (Gill)

tudinal incision in the capsule provides access to the inside of the joint which is further visualized by traction on the arm If more exposure is desired a transverse cut may be added to the longitudinal capsular incision at the glenoid margin

Both the glenoid and the head of the humerus are denuded of all cartilage down to cancellous bone Two drill holes are made in the base of the acromion and two in the head of the humerus Stout chromic catgut sutures are passed through the drill holes but not tied The capsule is closed then the sutures are tied over the capsule After discarding the detached portion of acromion process the deltoid is reattached posteriorly to the spine of the scapula to prevent backward displacement of the head of the humerus.

Combined Intra articular and Extra articular Arthrodesis (Gill) Gill's operation is relatively simple It was designed especially for nontuberculous affections of the shoulder joint The author has used it in tuberculosis of the shoulder without unfavorable sequelae Theoretically surgical trauma inflicted by performing an intra articular arthrodesis on a tuberculous joint favors the development of undesirable and serious complications In practice however this is not true Therefore Gill s method has been employed in many cases of tuberculous arthritis of the shoulder without fear of incurring distressing complications which, as yet the author has never encountered

A U incision is made about 2 centimeters below and around the margin of the acromion Beginning at the center of the incision, a vertical limb is extended from 2 to 2½ inches downward on the lateral aspect of the shoulder The deltoid is detached from the acromion process by sharp sub-

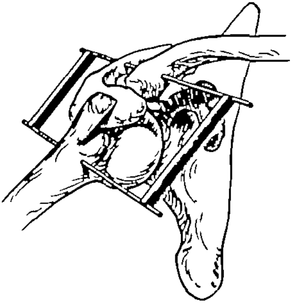


Fig 349 Method of obtaining compression following arthrodesis of the scapulohumeral joint (author s method)

periosteal dissection and reflected downward exposing the upper end of the humerus the subacromial bursa and the musculotendinous cuff Also by sharp dissection with a sharp thin osteotome the superior and the inferior surfaces of the *acromion are denuded next leaving the* periosteum attached proximally on the superior surface

A longitudinal incision in the capsule exposes the articular surfaces of the glenoid cavity and the humeral head The upper portion of the capsule is detached from the brim of the glenoid cavity and then together with the tendinous portion of the rotator cuff is excised up to an inch of its insertion into the greater and the lesser tuberosities A sharp curette readily removes the cartilage from the glenoid cavity and a sharp thin osteotome removes it from the humeral head A thin osseous flap is elevated upward from the anterolateral surface of the humerus A wedge-shaped piece of bone with its base upward is removed from the remaining portion of the head The denuded acromion process fits snugly into the humeral defect upon abducting the humerus The capsule and cuff attached to the head of the humerus are anchored by stout mattress sutures to the intact periosteum and fascia on the superior surface of the acromion thus ensuring maintenance of the humeral position (Fig 348)

Arthrodesis by Compression. The principle of compression has been added by the writer to the operation designed by Gill Its advantages justify its usage By the simple method about to be described, the head is held in the desired position in relation to the glenoid, the tendency of the head to be displaced posteriorly is overcome and by maintaining constant contact between the raw bone surfaces, early union is assured

After the arthrodesing operation is com*pleted the skin is closed,* and the arm is placed in the optimum position of function a stab wound is made 1 centimeter medial to the acromioclavicular articulation on the anterior surface of the clavicle. A small hole is drilled through the entire thickness of the clavicle parallel with the acromioclavicular joint. A Steinmann pin $\frac{7}{64}$ inch in diameter is inserted through this drill hole The pin is passed posteriorly through the spine of the scapula and the skin on the posterior aspect of the shoulder

A similar pin is inserted through the head of the humerus from before, backward, below the implant of the acromion into the humeral head parallel with the first pin (Fig 349) Both pins are incorporated in the plaster cast After the cast has hardened *the ends of the pins are freed by cutting* away the plaster of Paris between and around the pins forming a rectangular slot in front and behind (Fig 350 *top*) Positive pressure is created between the raw bone surfaces of the scapula and the humerus by stout rubber bands passing around the ends of the pins Constant compression is maintained for 5 weeks then the pins are removed Roentgenographic studies usually evidence osseous union by this time

Position of Optimum Function

As previously noted many failures of shoulder joint arthrodesis can be attributed *to the poor functional position of the humerus* in relation to the scapula. In chil

dren, the position giving optimum function is for girls, 45° abduction 15 forward flexion and from 15 to 20 internal rotation (attained by tilting upward the flexed forearm from 25° to 30 above the horizontal plane) for boys 55° abduction and exercised to maintain this position while the plaster cast is applied The plaster spica jacket extends from the metacarpophalangeal joints to the trochanters and is molded over the iliac crests so that it sits firmly on the pelvis It is suspended on the opposite

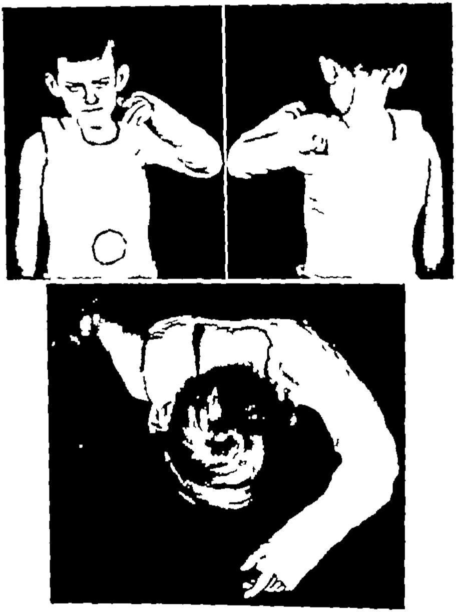


FIG 350 Position of extremity in plaster after arthrodesis of the scapulohumeral joint. Observe (*top right*) the slot cut out of the plaster and protruding ends of the pins which are being pulled together by rubber bands a similar slot is cut out of the front of the cast

25 forward flexion and the same amount of internal rotation

After the arthrodesing operation is completed and the humerus is placed in the position of optimum function care must be shoulder by a wide plaster strap (Fig 350)

Generally without using compression osseous union is achieved in 8 to 12 weeks in nontuberculous cases In those employing compression union occurs in 5 weeks.

However, whether compression is or is not used, immobilization of the shoulder is maintained for a minimum of 12 weeks. In cases not using compression if bony union is not demonstrable by roentgenographic study at the end of this time, another plaster cast is applied for 8 more weeks

As a rule, in tuberculous shoulders the period of immobilization is longer before firm bony union is attained Compression in arthrodesis of tuberculous shoulders ensures bony union decreases the period of immobilization and prevents loss of the desired optimum position of the humerus in relation to the scapula Rarely is immobilization necessary after 5 months No abduction splints are used after the plaster is removed

Removal of the cast is followed by an intensive regimen of active exercises which aim to attain the maximum amount of motion in the extremity by increasing the functional capacity of the muscles of the scapula the arm and the forearm and to restore normal motion in the elbow and the wrist joints

MUSCLE TRANSPLANTATIONS

Generally muscle transplants for paralytic disorders of the shoulder joint fail to give satisfactory results The Research Committee of the American Orthopedic Association studied 62 transplants in 43 patients and observed that the only satisfactory transplantations were in individuals possessing fair power in the deltoid muscles before operation (8 cases) The best results were attained in cases in which a strong posterior deltoid was transplanted anteriorly to the acromion and the outer third of the clavicle (3 cases) The committee questions the value of the Nicola procedure to stabilize paralytic subluxation. A strip of fascia lata was employed in 1 case to tie the scapulae together, in an effort to stabilize the shoulders. No improvement in function was attained by this procedure It became apparent from the afore mentioned observations that arthrodesis of the scapulohumeral joint is the operation of choice to achieve optimum function in a paralytic shoulder provided that there is sufficient power in the upper trapezius and the upper two-thirds of the serratus anterior muscles to motivate the scapula

PARALYSIS OF THE DELTOID MUSCLE

Paralysis of the deltoid most frequently results from acute anterior poliomyelitis It may be due to such trauma as dislocation of the glenohumeral joint and gunshot wounds in this region Also it may be caused by obstetric lesions. Careful evaluation of all the muscles of the extremity is essential when contemplating muscle transplantation for a paralyzed deltoid—a procedure justified only when the other muscles particularly the upper trapezius and the pectoralis muscles, have sufficient power to ensure better function.

Muscle transplants are contraindicated in cases with weakened power in the elbow and the hand. Arthrodesis of the scapulohumeral joint in the proper angle of abduction provides more stability and improves function in these cases Muscle transplants employed to stabilize paralytic dislocations have also proved to be ineffective The Nicola operation or one of its modifications is the most popular procedure. Here again, arthrodesis of the shoulder joint is the preferred method of stabilization. The most popular muscle transplantations are

1 Extension of the trapezius muscle by virtue of a graft of fascia lata and insertion of the graft into the humerus at the insertion of the deltoid

2 Transference of the biceps and the triceps to the acromion

3 Transference of the posterior portion of the deltoid to the anterior aspect of the acromion and to the outer third of the clavicle, and

4 A combination of any of the above methods

TRANSPLANTATION OF FASCIAL EXTENSION OF THE TRAPEZIUS MUSCLE (MAYER)

This procedure is indicated only when there is good power in the trapezius the pectoralis major and the scapular muscles particularly the serratus anterior the rhomboidei and the levator scapulae The best functional results are obtained when the deltoid possesses some power

Operative Technic

A U skin incision is made around the

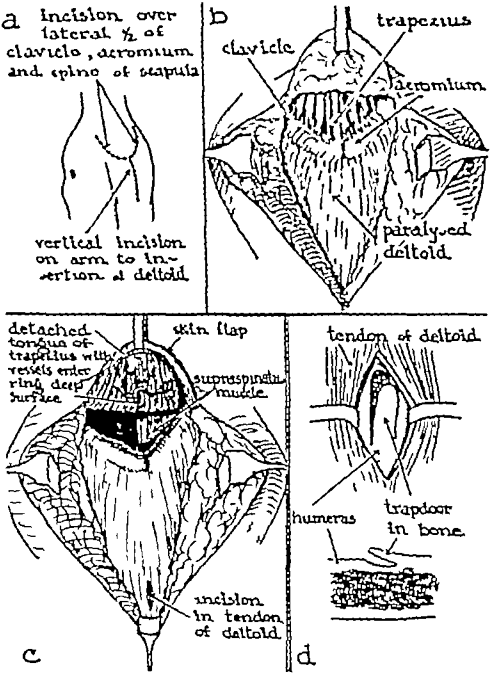


Fig 351A Extension of the insertion of the trapezius muscle to the deltoid tubercle by a graft of fascia lata. (a) Skin incision (b) Skin flaps have been reflected disclosing the underlying trapezius muscle and paralyzed deltoid muscle. (c) Trapezius muscle is detached from the clavicle acromium and spine of the scapula then reflected upward a verticle incision is made in the tendon of the deltoid down to the cortex of the humerus. (d) Trapdoor is made in the lateral aspect of the humerus. (Mayer and Lewis Practice of Surgery vol 3 p 82 Hagerstown Prior)

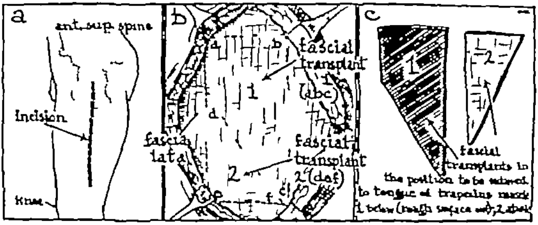


FIG 351B Extension of the insertion of the trapezius muscle to the deltoid tubercle by a graft of fascia lata (*continued*) (a) Longitudinal skin incision on the lateral aspect of the thigh (b and c) A rectangular piece of fascia lata 9 x 4 is removed and divided into a large and small triangular piece corresponding to fascial transplant 1 and 2 (Mayer and Lewis Practice of Surgery Vol 3 p 83, Hagerstown Prior)

shoulder girdle extending along the anterior surface of the clavicle around the acromion and along the spine of the scapula A second vertical skin incision is made in the lateral surface of the shoulder beginning at the acromion and terminating at the deltoid tubercle of the humerus The skin on the top of the shoulder is reflected medially exposing the insertion of the trapezius This is divided and reflected upward from the clavicle the acromion and the spine for from 3 to 4 inches at which point the blood vessels and the nerves penetrate its deep surface

Anteriorly the plane of dissection lies between the trapezius and the outer border of the sternocleidomastoid muscle posteriorly between the trapezius and the supraspinatus muscle The anterior and the posterior flaps of the vertical skin incision are dissected away from the top of the deltoid until the entire muscle is exposed A vertical slit from 1 to 1½ inches down to the bone in the insertion of the deltoid is then made Through this slit a bone flap is elevated from the lateral aspect of the humerus A graft of fascia lata from 3½ to 4 inches wide and about 9 inches in length is removed from the lateral aspect of the thigh. The fascial transplantation is divided into a long graft and a short graft as shown in Figure 351 The rough surface of the longer graft is placed in contact with the deep surface of the trapezius and is anchored by interrupted sutures The smaller graft covers the outer surface of the muscle and is sutured to both the muscle and the longer graft The trapezius is now enveloped in two layers of fascia lata

Next with the arm abducted 135 from the trunk and flexed forward about 20 the edges of the long fascial graft are sutured to the anterior and the posterior borders of the deltoid Finally the pointed end of the long graft is anchored in the slit beneath the bone flap raised from the humerus

Postoperative Management

A plaster shoulder spica is applied holding the arm in 135 abduction and 20 forward flexion After 4 weeks graduated active exercises are initiated although the arm is not permitted to drop to the side for 4 more months An abduction brace may be worn for the remaining period of immobilization after the first 4 weeks

TRANSPLANTATION OF BICEPS AND TRICEPS MUSCLES (OBER)

The success of this procedure as the transference of the trapezius muscle depends upon good power in the biceps and the triceps muscles and in the pectoralis

major and scapular muscles The best results are seen in cases with some power in the deltoid

Operative Technic

A superior skin incision is made over the acromion process The anterior limb extends downward 3 inches over the anterior aspect of the shoulder the posterior limb is carried downward and slightly inward for 3 inches over the posterior aspect of the shoulder The anterior segment of the incision is deepened through the fibers of the deltoid exposing the coracoid process and

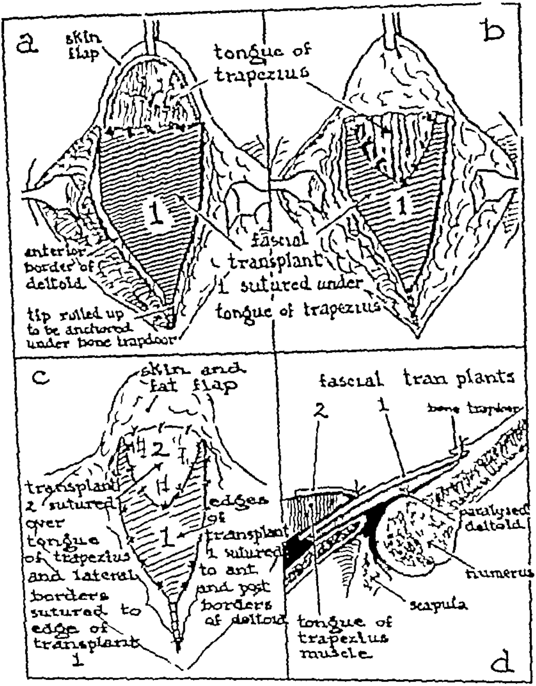


FIG 351C Extension of the insertion of the *trapezius* muscle to the deltoid tubercle by a graft of fascia lata (*continued*) (a) Fascial transplant 1 is sutured to the undersurface of the trapezius muscle (b) The edges of the *tongue* of the trapezius are sutured to fascial transplant 1 (c) Fascial transplant 2 is sutured over the tongue of the trapezius and its lateral edges tacked to transplant 1 (d) The top of transplant 2 is rolled up and anchored beneath the trapdoor on the lateral aspect of the humerus, while the arm is held in a position of abduction. (Mayer and Lewis Practice of Surgery, Vol 3 p 84 Hagerstown, Prior)

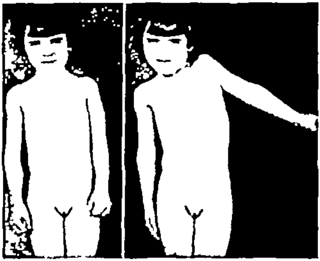


FIG 352 (*Above*) Patient before transplantation of the biceps and triceps tendons who had limited power in the deltoid muscle. (*Right*) Patient after operation, showing range of elevation of the arm. (Ober J.A.M.A. 99 2182)

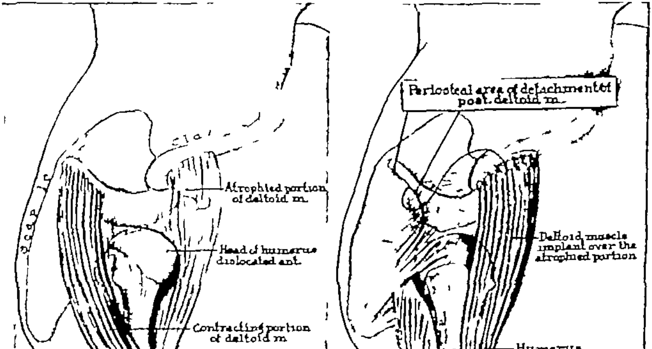


FIG. 353 Transplantation of the origin of the posterior portion of the deltoid muscle to an anterior position. (Harmon P G Surg Gynec. & Obst. 84 117 118)

its muscular attachments The tendon of the short head of the biceps is identified dissected free from the coracobrachialis and the pectoralis minor and detached from the coracoid with a small portion of its bony insertion It is then separated from surrounding structures down to the tendon of the pectoralis major

If the biceps tendon is too short to reach the top of the acromion the upper half of the tendon of the pectoralis major may have to be severed to gain length Next the posterior arm of the skin incision is developed to expose the long head of the triceps muscle at its origin on the scapula The tendon with a small portion of its bony attachment is removed from its scapular origin Together with the attached muscle it is then dissected from the surrounding structures on the upper end of the humerus With a thin osteotome two cuts are made in the acromion one anterior and one posterior for the biceps and the triceps tendons respectively The cuts are made parallel with the flat surface of the acromion and their edges are spread to receive the tendons. Both tendons are passed through the fibers of the deltoid to emerge near the top of the acromion opposite their respective bone cuts The tendons are anchored therein with interrupted silk sutures, while the arm is being held in an abducted position Postoperative management is the same as described for the transplantation of the trapezius muscle

TRANSPLANTATION OF THE ORIGIN OF THE POSTERIOR PORTION OF THE DELTOID

Occasionally the posterior portion of the deltoid is not implicated while the remaining portions disclose complete paralysis Ober believes that transferring this segment to an anterior position increases the function of other muscle transplants about the shoulder However as previously stated it appears that the only transplants to function adequately are those performed in individuals who possess some power in the deltoid Harmon has employed this procedure to restore power of abduction to the extremity and also to cure recurrent dislocation of the glenohumeral joint associated with paralysis of the anterior and the middle portions of the deltoid

Operative Technic (Harmon)

A semicircular incision is made around the shoulder just below the acromion The incision proceeds along the lower border of the middle third of the clavicle around the acromion, to the middle of the spine of the scapula The entire line of insertion of the deltoid is exposed by reflecting the skin flaps upward and downward The scapular origin of the deltoid is freed subperiosteally with a sharp thin osteotome, and the upper half of the muscle is mobilized by separating it from the surrounding structures

Care must be exercised during this stage of the operation not to traumatize the axillary nerve and the posterior axillary artery as they emerge from the quadrilateral space and continue anteriorly on the deep surface of the muscle A new site of insertion is now prepared on the anterior surface of the outer third of the clavicle by exposing the bone by sharp subperiosteal dissection. The scapular origin is transferred anteriorly and attached by interrupted sutures to the edge of the periosteum on the superior surface of the clavicle The extremity is immobilized in a plaster shoulder spica in 105° elevation in the frontal plane. Postoperative management is similar to that described for the method of Mayer and Ober

FASCIAL TRANSPLANTS IN PARALYTIC DISORDERS ABOUT THE SHOULDER GIRDLE

Muscle imbalance resulting from infantile paralysis in the cervical region and the scapular muscles may be responsible for extensive deformities of the cervicothoracic and the upper thoracic regions of the trunk and the shoulder girdles Such deformities

are difficult to control and more difficult to correct Dickson, stimulated by the work of Lowman and of Mayer, designed several fascial transplants which tend to stabilize cervicothoracic curves—also cases with involvement of the scapular muscles

PARALYSIS OF THE SPINAL AND THE ELEVATOR MUSCLES OF THE SCAPULA

Paralysis or weakness of the spinal and the elevator scapular muscles may lead to severe high cervicothoracic scoliosis and dropping of the shoulder on the affected side. In these cases the goal is to elevate the depressed shoulder and to stabilize the deformity which is progressive in nature by creating a fixator action against the pull of the unaffected muscles on the convexity of the cervical curve Dickson reports satisfactory results with the following procedure Moreover the function of the entire upper extremity improves and fatigue and neck pain are lessened

Operative Technic (Dickson)

Two long strips of fascia lata rolled into tubes with the gliding surfaces out are employed in this operation A skin incision of from 3 to 4 inches is made over the outer extension of the spine of the scapula close to the acromial end the spine is exposed subperiosteally and a slot is made through it A second incision is made from the spine to the apex of the cervical curve on the concave side exposing the underlying cervical fascia. The end of one of the fascial tubes is now laced to the cervical muscles at the apex of the curve on its concave side The dropped scapula is elevated as high as possible, and while this position is being maintained the other end of the fascial tube is passed through the slot in the spine and sutured to itself with interrupted silk sutures.

A third incision is made over the spinous process of the first thoracic vertebra and a hole is drilled through its base One end of the second fascial tube is drawn through a slot made in the vertebral end of the spine and anchored to itself The other end traverses a subcutaneous tunnel, emerging at the spinous process of the first thoracic vertebra, it passes through the hole and is sutured to itself under tension

Postoperative Management

The arm is immobilized in a plaster spica in from 40 to 50° abduction, or the arm is attached to the head of the bed Active exercises are begun after 3 weeks. All support is discontinued after 5 or 6 weeks

PARALYSIS OF THE SERRATUS ANTERIOR MUSCLE

Weakness or paralysis of the upper spinal and scapular muscles is responsible for pronounced hypermobility of the scapula and promotes high thoracic and cervicothoracic curves. The serratus anterior functions primarily as a stabilizer of the scapula. In pushing movements it draws the scapula toward the thoracic cage in elevating it rotates the inferior angle upward and forward If the serratus anterior is implicated the scapula shifts toward the vertebral column and rotates downward and inward. Marked winging of the scapula occurs during arm elevation The deformity is particularly striking in the movements of pushing In the operation about to be described an attempt is made to stabilize the scapula, which in turn improves the shoulder function and also acts as a check to further progression of the spinal curvatures.

Operative Technic (Dickson)

First the scapula is displaced forward to the position desired in relation to the thoracic wall While it is held in this position an incision is made above the lower axillary border of the scapula, and a drill hole is passed through the inferior angle Through this hole the end of a tube made of fascia lata is passed and sutured to itself

A second incision is made on the lateral

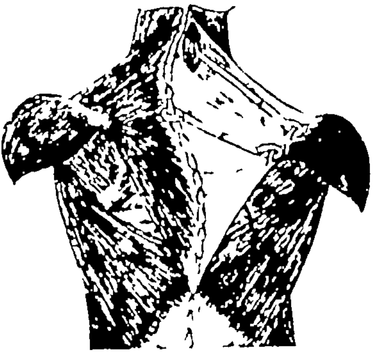


Fig. 354 Fascial transplants designed by Dickson for paralytic disorders about the shoulder joint. Dickson J Bone & Joint Surg. 19 408)

aspect of the thorax over the origin of the pectoralis major muscle the two skin incisions are connected by a subcutaneous tunnel through which the distal end of the fascial tube is passed The end of the tube is split into two halves one half is laced into the lowermost fibers of the pectoralis major the other into the anterior border of the latissimus dorsi Then the ends of the fascial tube are anchored under considerable tension while the scapula is held in the desired position Added stability of the scapula may be attained by running a second fascial tube from the cervical muscles to the spine of the scapula

PARALYSIS OF THE RHOMBOIDEI AND THE LEVATOR SCAPULAE MUSCLES WITH GOOD POWER IN THE SERRATUS ANTERIOR MUSCLE

With paralysis or weakness of the levator scapulae and the rhomboidei muscles the scapula shifts laterally toward the axilla During arm elevation its upper vertebral border is pulled downward and inward by the unapposed serratus anterior, in addition to a lateral shift of the scapula High thoracic scoliosis may be a concomitant finding the deformity tends to be progressive

Operative Technic (Dickson)

Two fascial transplants in the form of tubes are used in this procedure One extends from the lower vertebral border of the scapula to the spinal muscles the other from the inferior angle of the scapula to the latissimus dorsi muscle. A small incision is made over the lower vertebral border of the scapula, and a hole is drilled through the bone another small incision is made over the spinal muscles opposite and slightly inferior to the first incision The two incisions

are connected by a subcutaneous tunnel One end of a fascial tube is laced into the spinal muscles the other end traverses the subcutaneous channel, proceeds through the hole in the vertebral border of the scapula and is sutured on itself under tension

A third incision is made over the inferior angle of the scapula The bone is exposed subsequently and a hole is drilled through its substance. Another small vertical incision is made 3 inches medial and inferior to the inferior angle of the scapula, exposing the fibers of the latissimus dorsi Both incisions are also connected by a subcutaneous tunnel One end of the second fascial tube is laced into the fibers of the latissimus dorsi. The other passes through a tunnel hole in the inferior angle of the scapula and is sutured to itself under tension

As pointed out by Dickson the aforementioned procedures are useful in improving the overall function of the extremity They stabilize the scapula and may arrest partially the development of spinal deformities. More study of the usefulness and the indications of fascial transplants is necessary before definite conclusions can be drawn as to the merit of the procedures.

AMPUTATIONS

General Considerations

Every effort should be made to save as much of the upper arm as possible when amputation through this region is contemplated A stump of less than 4 inches is of no functional value because it is impossible to fit a workable prosthesis on such a short stump On the other hand the upper end of the humerus should be preserved if possible even if the desired stump length is not attainable since the normal contour of the shoulder girdle is retained Removal of the head of the humerus produces a narrow flat shoulder

The most desirable amputation incision through the upper end of the humerus is the racquet incision which creates a long lateral and a short medial flap In this method the lateral flap consisting of the deltoid muscle is utilized to cover the end of the humeral stump

Disarticulation of the shoulder is usually performed for severe traumatic injuries or malignant tumors implicating the upper arm. When feasible amputation through the upper arm is preferable to disarticulation As in amputation through the surgical neck of the humerus, the racquet incision provides both adequate exposure for rapid disarticulation and good flaps for easy closure.

Interscapulothoracic amputation is indicated for malignant lesions of the shoulder girdle, particularly when the component elements of the glenohumeral joint are implicated If the tumor is limited to the clavicle or the scapula, resection of these bones should be performed Loss of great amounts of blood may be minimized by first isolating and ligating the subclavian artery and vein

Amputation at the Level of the Surgical Neck

The patient is placed in a sitting position with the shoulder over the side of the table a sandbag under the shoulder and the arm draped separately the table is tilted about 30 away from the operator The handle of *the racquet incision begins on the anterior* surface of the arm at the lower border of the clavicle in the interval between the deltoid and the pectoralis major muscles. It continues downward along the anterior border of the deltoid to the level of the deltoid tubercle thence it curves outward to and continues along the posterior border of the deltoid to the posterior fold of the axilla.

Beginning at the lower end of the handle of the racquet incision the medial incision is carried around the inner aspect of the arm an inch below the axilla and meets the lateral incision The insertion of the pectoralis major muscle is divided and allowed to retract medially Next the axillary vessels and nerve trunks are exposed as they pass from beneath the pectoralis minor muscle medial to the coracobrachialis muscle The artery and the vein are isolated doubly ligated and divided. The nerve

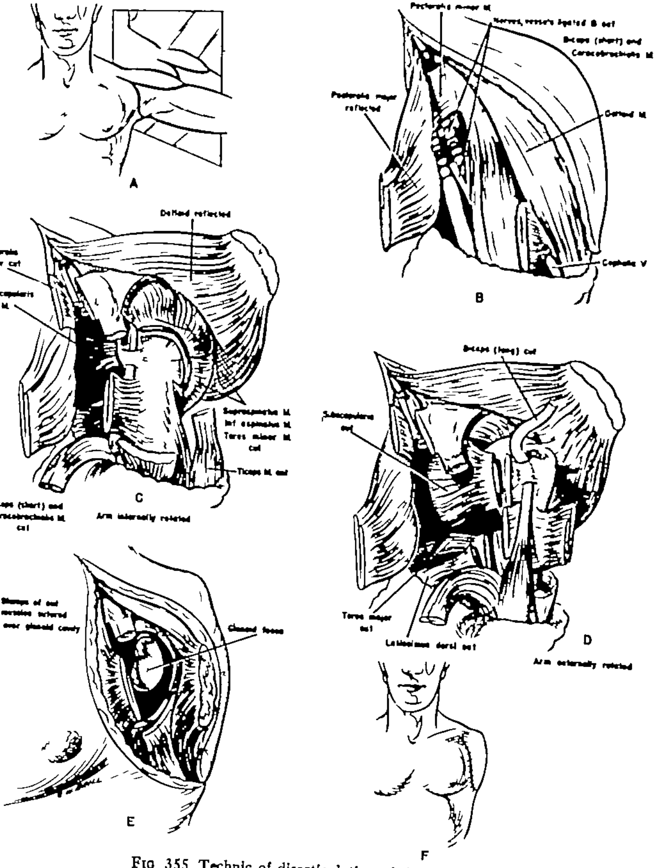
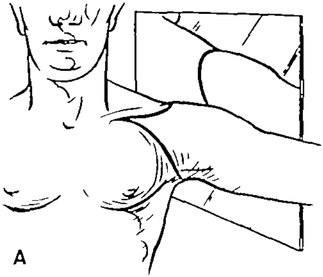


FIG 355 Technic of disarticulation of the shoulder

trunks (radial, median and ulnar nerves) are isolated, ligated and severed after being injected first with procaine, then with 75 per cent alcohol

No traction is made on the trunks before cutting them The tendinous insertion of the deltoid is then divided, and the muscle, together with the skin flap is reflected upward. Care is taken not to injure the axillary nerve The tendinous insertions of the latissimus dorsi and the teres major muscles are cut on the inner aspect of the humerus. The long muscles running parallel with the shaft of the humerus (biceps triceps and coracobrachialis) are severed approximately one inch below the contemplated level of the stump of the humerus Next, the humerus is sectioned through the surgical neck. The deltoid muscle is approximated and sutured to the muscles on the inner aspect of the stump of the humerus, and the skin edges are brought together with interrupted sutures.

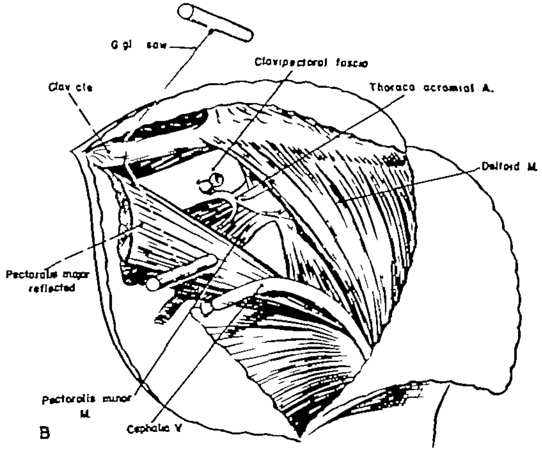


A

Disarticulation of the Shoulder

The patient is placed in the sitting position with the shoulder over the side of the table, a sandbag under the shoulder and the arm draped separately to allow easy maneuvering. The table is tilted 30° away from the surgeon

The vertical arm of the racquet incision begins on the anterior aspect of the arm



B

Fig. 356 Technic of interscapulothoracic amputation.

just below the lower border of the clavicle in the sulcus between the pectoralis major and the deltoid muscles It continues downward along the anterior border of the deltoid to the level of the deltoid tubercle then sweeps outward and continues along the posterior border of the deltoid to the posterior axillary fold A second transverse in

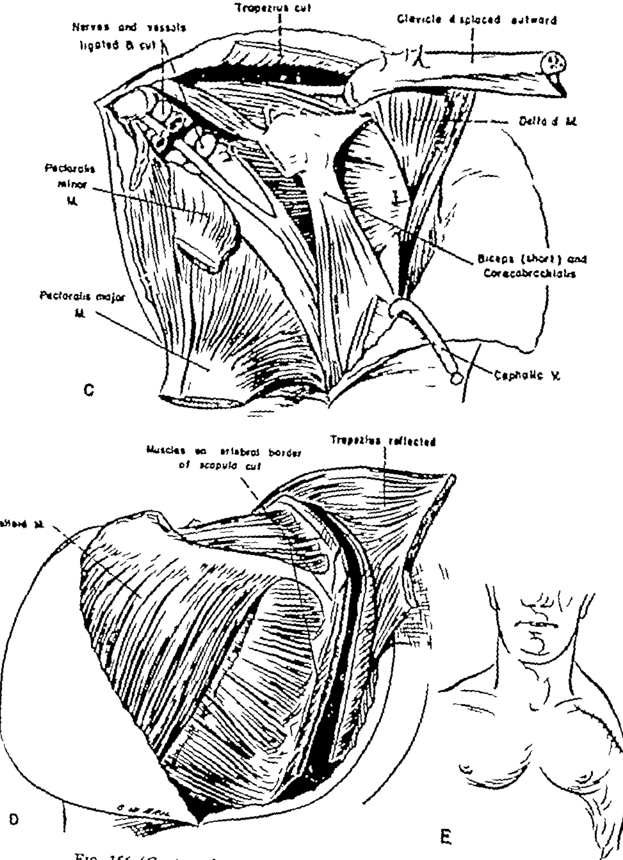


FIG 356 (*Continued*) Technic of interscapulothoracic amputation

cision is made, passing through the axilla connecting the two ends of the first incision The anterior arm of the incision is deepened, exposing the pectoralis major muscle, which is divided close to its insertion into the humerus Next, the sulcus between the coracobrachialis and the pectoralis minor muscles is developed exposing the axillary vessels and the nerve trunks The vessels are separated doubly ligated and divided between ligatures. The nerve trunks are ligated, injected with procaine then with 75 per cent alcohol and severed

The conjoined tendon of the coracobrachialis and the short head of the biceps muscle are cut at their insertion into the coracoid process The deltoid is divided at its point of insertion into the humerus then it is reflected upward together with the skin flap off the anterior surface of the humerus bringing into view the upper end of the humerus and of the musculotendinous cuff External rotation of the arm puts the subscapularis tendon on a stretch and together with the capsule it is cut close to its insertion into the lesser tuberosity Then the arm is rotated internally The tendon of the long head of the biceps muscle the remainder of the musculotendinous cuff and the posterior portion of the capsule are divided close to its insertion into the greater tuberosity By pulling downward on the arm the inferior capsule is visualized and cut.

Disarticulation is completed by dividing the remaining muscles on the anterior (teres major and latissimus dorsi muscle) and posterior (triceps muscle) aspects of the humerus All stumps of the severed muscles are sutured across the glenoid cavity The lateral flap is approximated to the medial flap and the skin edges are brought together by interrupted sutures. Drainage of the wound for the first 24 hours is advisable because of the amount of secretion that follows this procedure Dry dressings are applied to obliterate all dead spaces After 24 hours the drain is removed and a compression dressing is applied (Fig 355)

Interscapulothoracic Amputation

The patient is placed in a sitting position with the shoulder well over the side of the table, a sandbag under the shoulder, and the arm draped separately to permit easy maneuvering of the limb The head is drawn in the opposite direction The table is tilted 30 away from the operator thereby making both the front and the back regions of the shoulder accessible A linear skin incision is made on the anterior surface of the clavicle beginning at the outer border of the sternocleidomastoid muscle and carried outward crossing the acromioclavicular joint

A second incision starts at the lower border of the center of the clavicle and continues downward in the interval between the deltoid and the pectoralis major to the lower border of the anterior axillary fold Before making the axillary and the posterior portions of the skin incision, the clavicular incision is carried down to the bone and the clavicular portion of the pectoralis major muscle is stripped subperiosteally from its bony attachment The clavicle is then divided with a Gigli saw at the junction of its middle and inner thirds. The outer segment of the clavicle is freed from all soft tissue attachments and is removed by cutting it free at the acromioclavicular joint

The interval between the pectoralis major and the deltoid muscles is developed exposing the coracoid process The pectoralis major is divided close to its insertion into the humerus and is allowed to retract medially The pectoralis minor is severed at the tip of the coracoid process By developing the interval between the pectoralis minor and the coracobrachialis muscles the large vessels and the nerve trunks are brought into view The subclavian artery and vein are separated doubly ligated and cut between ligatures. The nerve trunks are freed injected with procaine then with 75 per cent alcohol and divided Next the latissimus dorsi is divided and the limb falls outward from the trunk

The clavicular incision is now extended backward over the shoulder along the vertebral border of the scapula to the inferior angle then sweeps outward to the posterior axillary fold The arm is raised, and the anterior incision is continued across the axilla to meet the posterior incision With the arm carried across the chest the posterior flap is reflected to expose the trapezius muscle which is detached from the scapula All muscles running from the thorax to the vertebral border of the scapula are severed from above downward, and the limb is removed with complete severance of all muscular attachments to the scapula

All muscle stumps particularly those of the pectoralis major and the trapezius are sutured to the chest wall Bleeding vessels are ligated the flaps are tailored and the wound is closed with interrupted sutures In most cases a drain is advisable in the dependent portion of the wound for 1 or 2 days Dry dressings are firmly applied to eliminate dead tissue spaces (Fig 356)

RESECTIONS

Excision of the Acromion Process

Hitherto the most common cause for shoulder pains associated with arm movements particularly abduction was believed to be impingement of the supraspinatus tendon against the acromion process Although the above mechanism is responsible in some cases the study described in the chapter on bicipital syndromes leads one to conclude that the most common etiologic factor for painful shoulders is bicipital tenosynovitis Nevertheless it must be admitted that in a small group of patients friction and impingement of the supraspinatus tendon against the acromion process will cause pain on abduction of the arm The symptom complex is referred to as the supraspinatus syndrome

Normally when the arm is abducted the greater tuberosity readily glides under the acromion or the coraco-acromial ligament with minimum friction and no impingement. However in the presence of certain alterations in the musculotendinous cuff the subacromial bursa and greater tuberosity these structures actually impinge against the acromion or the coraco-acromial ligament, causing pain on abduction of the arm Pain is felt as these structures pass under the coraco-acromial arch once they have passed under the arch abduction is completed without pain The painful arc of abduction is usually between 80° and 120

Following acute incomplete or complete tears of the musculotendinous cuff the disrupted tendinous tissue is swollen edematous, inflamed and thickened Therefore it is apparent that such tissue will be compressed readily against the acromion during abduction of the arm and produce a painful arc of movement When the acute inflammatory process has subsided and the scar tissue contracts the torn portions of the cuff shrink in thickness It will now pass under the acromion with minimum friction and without impingement or pain on abduction of the extremity

Old incomplete tears of the cuff in themselves do not give rise to painful motion It has been demonstrated in the chapter on degenerative lesions of the shoulder joint that in many cases exhibiting such lesions the cuff still attached to the head of the humerus may be thinned frayed, shredded or absent, while the torn fibers on the proximal side of the tear may be thickened and hypertrophied Nevertheless these alterations may allow free painless movements at the shoulder joint

In such instances, there are often secondary hyperplastic inflammatory changes in the walls of the subacromial bursa which may become so thickened that the bursal sac impinges against the acromion when the arm is abducted thereby causing pain Increased friction and impingement against the acromion favor more pronounced inflammatory changes in the bursal walls establishing a vicious cycle

Also, complete and incomplete tears are often associated with the formation of bony

excrescences over the greater tuberosity which impinge against the acromion on arm abduction. Bony excrescences and a hyper trophied subacromial bursa are often con comitant lesions in the same shoulder Oc casionally, calcareous masses within the substance of the cuff may impinge against the acromion Extensive ossification may occur in the musculotendinous cuff Im pingement of the ossified tissue against the acromion may result in pain and restricted motion.

Most individuals with acute injuries to the musculotendinous cuff recover either spontaneously or after a period of rest and physical therapy When the causative fac tors of pain are impingement against the acromion of a thickened bursal sac or bony excrescences pain is alleviated by excising the bursa or the bony excrescences In ad dition all or part of the acromion should be resected to prevent their re formation Likewise in cases with ossification within the cuff, in which excision of the ossified mass is not practical, resection of the acromion is the procedure of choice In all in stances of repaired rupture of the musculotendinous cuff the acromion should be resected This added procedure not only facilitates the operation but removes any source of friction and impingement on the reattached cuff

Smith Petersen points out that acromioplasty relieves pain and muscle spasm and increases shoulder girdle motion in patients afflicted with atrophic arthritis Although the operation does not increase motion ma terially in the glenohumeral joint it does alleviate pain and muscle spasm, thereby increasing motion in the thoracoscapular joint—hence improving the over all useful ness of the extremity He advocates per forming the operation for subacromial bursitis a concomitant lesion of atrophic arthritis of the shoulder before osseous changes are roentgenographically demon strable.

Operative Technic. The patient is placed in a sitting position, with the shoulder well over the side of the table and a sandbag under the shoulder The table is tilted 30 from the operator, and the arm is draped separately

A short saber incision is made just to the outer side of the acromioclavicular joint, beginning at the anterior border of the acromion and extending backward across the acromion to its posterior border The incision is deepened to the bone, and the central deltoid muscle fibers are detached subperiosteally from the acromion with a sharp osteotome and reflected laterally The acromion is divided approximately 1 centi meter to the outer side of the acromiocla vicular joint in an anteroposterior direction with an osteotome

Excision of the acromion exposes the roof of the subacromial bursa. As a rule the bursal walls are thickened and disclose evi dence of a chronic inflammatory process As complete a synovectomy as possible is per formed By retracting the edges of the wound and rotating the arm internally and externally the entire musculotendinous cuff can be inspected thoroughly Closure is achieved by suturing the detached deltoid muscle to the periosteum on the top of the acromion

The entire acromion may be removed without impairing the stability of the acromioclavicular joint, so long as the coracoclavicular ligaments remain intact The plane of division of the acromion traverses the acromioclavicular joint thereby sever ing the acromioclavicular ligaments. If the entire acromion has been resected the del toid muscle is sutured to the acromiocla vicular ligaments and to the reflected peri osteum. The skin edges are approximated by interrupted sutures and a dry dressing is applied making firm pressure over the wound

Postoperative Management. A sling provides sufficient immobilization of the ex tremity Active motion at the elbow the wrist and the hand is encouraged immedi ately However active shoulder motion is not permitted until the postoperative reac

tion about the shoulder recedes Pendulum exercises are begun after the fourth or fifth day and active abduction of the extremity against gravity is not begun until after the tenth or twelfth day By this time, active contraction of the deltoid will not elicit pain Optimum restoration of function should be attained in from 6 to 8 weeks

Resection of the Scapula

Coley points out that capulectomy is justifiable as an alternative to interscapulothoracic amputation in malignant lesions of the scapula where the entire tumor can be removed Also such benign lesions as chondromas, which cannot be successfully removed by partial excision may be removed by resection of the scapula Localized destructive lesions such as chronic osteomyelitis and tuberculosis and benign tumors such as osteochondromas may be dealt with by partial resection of the scapula.

Operative Technic of Total Resection The patient is placed on the unaffected side close to the edge of the table the arm is draped separately Two skin incisions are made the first begins just lateral to the tip of the acromion process and extends along the spine to the vertebral border of the scapula the second incision is a continuation of the first downward along the vertebral border to the inferior angle of the scapula The resulting flaps are reflected exposing the dorsal surface of the scapula The horizontal limb of the incision is deepened to the bone thereby severing the tendinous insertions of the trapezius and the deltoid muscles which are next detached from the acromion process and the spine of the scapula and retracted The deltoid is also detached from the outer third of the clavicle to bring into view the coracoid process with its muscular attachments the coracoclavicular ligaments and the insertion of the rotator muscles

The acromioclavicular ligaments are severed and the scapula is mobilized further by dividing the muscular attachments to its vertebral border the levator scapulae the rhomboids, the serratus magnus and the teres major muscle Then the muscular attachments to the coracoid process the coracoacromial ligament and the coracoclavicular ligaments are divided

Finally by a curved incision around the upper end of the humerus the four short rotator tendons are divided from before backward This sweeping incision will also sever the coracohumeral ligaments and the tendon of the long head of the biceps brachii muscle Resection of the bone is completed by cutting the remaining portion of the fibrous joint capsule and the muscular attachments. After all bleeding has been controlled the trapezius and the deltoid muscles are approximated and the skin incisions are closed with interrupted sutures A drain is placed in the dependent part of the wound, it is removed after 24 or 48 hours Dry dressings are applied, making firm pressure on the wound The arm is immobilized by a Velpeau bandage

Postoperative Management Early active motion is encouraged in the joints distal to the shoulder Although shoulder function is greatly impaired by this procedure some useful function is retained in the upper extremity and the operation is by far more desirable than interscapulothoracic amputation when feasible

Operative Technic of Subperiosteal (Partial or Total) Resection of Scapula (Ollier) Varying amounts of the body of the scapula or the entire bone may be excised by this method. Two skin incisions are made One begins at the tip of the acromion and extends along the spine of the scapula to its posterior border The other starts at the posterosuperior angle of the scapula continues along the vertebral border and ends at the inferior angle By sharp subperiosteal dissection the muscular attachments (trapezius and deltoid muscles) are reflected from the spine and the acromion process The periosteum along the posterior border in the interval between the infraspinatus muscle and the insertion of the

rhomboid major is divided and reflected from the infraspinous fossa.

The superior border of the scapula is exposed in a similar manner, and the periosteum is elevated from the supraspinous fossa Care must be exercised at this point not to traumatize or cut the suprascapular vessels and nerve as they enter the suprascapular notch Next the inferior angle is raised and the subscapularis muscle is stripped subperiosteally from the subscapular fossa the posterior border is detached completely from any muscular attachments

Subperiosteal stripping on the ventral surface of the scapula can now proceed as far as the anterior surface of the neck of the scapula Any portion of the scapula can be removed with this exposure The bone may be divided below the base of the spine, or through the neck of the scapula, or the entire scapula can be removed by subperiosteal stripping of all the ligaments attached to the neck

Resection of the Outer End of the Clavicle

This procedure may be performed for chronic subluxation or hypertrophic arthritis of the acromioclavicular joint. It is especially indicated in older individuals and in those who do not perform strenuous work The operation gives a very good functional result, alleviates pain reduces the period of disability and improves the cosmetic effect of the shoulder However most individuals who undergo the operation believe that the shoulder is not so strong as the unaffected one The resection is not performed for complete dislocations of the joint in which the coraco-acromial ligaments are disrupted If a resection of the outer end of the clavicle is done in these cases reconstruction of the coraco-acromial ligaments should supplement the procedure.

Operative Technic (Gurd and Mumford) A small curved incision is made over the acromioclavicular joint. The distal end of the clavicle is exposed subperiosteally and raised with bone forceps and brought forward, while a Gigli saw is passed beneath it The distal 1 or 1½ inches of the clavicle is sawed off and removed The meniscus, if present, is excised

Finally, the periosteal tube is reefed and closed, covering the cut surface of the clavicle The skin edges are approximated with interrupted sutures and the arm is immobilized in a Velpeau bandage. Active use of the arm is encouraged after a week. Full restoration of shoulder motion should be complete in from 4 to 6 weeks.

Resection of the Inner End of the Clavicle

This procedure may be employed in chronic dislocations of the sternoclavicular joint which are causing shoulder dysfunction but in which reconstructive measures are contraindicated or in cases in which reconstructive procedures have failed Occasionally pronounced degenerative lesions of the sternoclavicular joints are encountered, producing pain and disability Here resection is a justifiable procedure

Operative Technic. The sternoclavicular joint is exposed through a 2 to 3 inch incision the sternal end of the clavicle is exposed subperiosteally, cut with a Gigli saw and removed The periosteal tube is plicated and closed over the raw end of the clavicle the skin wound is closed with interrupted suture and the arm is immobilized in a Velpeau dressing Active use of the shoulder is encouraged after a week. Full function should be achieved in from 4 to 6 weeks

Total Excision of Clavicle

Fortunately the indications for total excision of the clavicle are few, since the close proximity of many vital structures make this a formidable procedure Tumors of low grade malignancy giant-cell tumors benign tumors (which cannot be dealt with by subtotal excision) and necrosis of the clavicle, as seen in chronic osteomyelitis and tuberculosis are the chief indications for total excision Tumors may distort the normal

anatomic arm relationship and great difficulty may be encountered in excising the bone without injury to surrounding structures Then too, greater danger exists in expirating the middle and inner third of the clavicle than the outer third Whenever possible the plane of dissection should hug the bone closely The structures more vulnerable to injury are the subclavian vessels the cephalic vein the innominate vein on the right, the external jugular vein the thoracic vein *on the left* the pleura and the brachial plexus

Operative Technic. A horizontal skin incision is made in the long axis of the bone from the sternal to the acromial end If the operation is for the removal of a tumor the skin flaps are dissected from the tumor and retracted The attachments of the deltoid and the trapezius muscles are divided Excision is facilitated by dividing the clavicle and removing the two segments separately or severing the acromioclavicular and the coracoclavicular ligaments thereby mobilizing the acromial end of the clavicle The outer end is then raised anteriorly Together with the tumor mass it is dissected carefully from the surrounding structures. Lastly the sternoclavicular ligaments are severed and the clavicle is removed

Loss of part of or all the clavicle does not seriously impair shoulder function nor does it cause a forward droop of the shoulder

Resection of the Upper End of the Humerus

It may be necessary to resect the upper end of the humerus for gunshot injuries giant-cell tumors which exhibit malignant transformation or low grade malignant neoplasms Occasionally following fracture dislocation of the humerus the head fragment must be removed, either because of severe comminution or *complete disruption* of its blood supply

Resection for Neoplasms and Fibular Transplantation. The upper end of the humerus is best exposed by the Cubbins or Henry's incision the latter being preferred by the author The anterior limb of the incision extends along the anterior border of the deltoid muscle, beginning at the lower border of the clavicle over the deltopectoral sulcus and ending at the level of the deltoid tubercle The horizontal limb is a continuation of the upper end of the anterior incision along the outer third of the clavicle extending backward over the tip of the acromion to the spine of the scapula After the plane between the deltoid and the pectoralis *major muscle* is developed the origin of the deltoid is detached from the clavicle and the acromion process with a sharp osteotome and is reflected downward and outward exposing the upper end of the humerus

A vertical incision is then made in the musculotendinous cuff preferably in the interval between the subscapularis and supraspinatus muscles The rotator muscles are severed close to their insertion into the greater and the lesser tuberosities the biceps tendon is left intact and displaced inward and the inner aspect of the upper end of the humerus is freed of all muscular attachments

Finally, the inferior portion of the capsule is cut from the neck of the humerus and the lateral head of the triceps muscle is detached from the humerus by sharp dissection care being exercised to avoid injury to the musculospiral nerve as it swings around the upper end of the bone The upper end of the humerus then is projected through the wound and severed several inches distal to the neoplasm through good bone

The upper end of the fibula may be utilized to restore the length of the humerus and to provide some stability to the shoulder joint The articular surface of the fibular head is placed in opposition to the glenoid cavity and its distal end is cut to fit into a notch made in the lateral aspect of the shaft of the humerus The ends of the bones are fixed by two screws, or else the distal end of the fibular graft is inserted into the medullary cavity of the humerus No

attempt is made to restore the function of the short rotator muscles The deltoid is reattached to the clavicle and the acromion process, and the skin is closed with interrupted sutures.

The extremity is immobilized for 12

Fig 357 (*Left*) Giant-cell tumor of the left humerus the tumor and the upper end of the humerus were resected and replaced by a fibular transplant as shown in the center frame. (*Center*) Fibular transplant of case shown at left, 29 months after operation. (*Right*) Fibular transplant done for a chondrosarcoma of the upper end of the humerus. A Kirschner wire has been passed through the medullary canal of the fibula as a prophylactic measure against possible fracture of the graft. (J B Moore)

weeks in a plaster-of Paris shoulder spica, with the arm held in abduction of from 45° to 60° After this interval the arm portion of the spica is bivalved to permit physical therapy and active motion of the elbow and the wrist. The cast is removed after 4 more weeks, but the arm is protected with an abduction brace for several months until bone healing is roentgenographically demonstrable.

Resection of the Humeral Head

McLaughlin s transacromial incision provides adequate exposure of the upper end of the humerus allowing this operation to be performed without danger of injury to the brachial vessels and nerves when the head of the humerus is extracted from its dislocated site from above

An anteroposterior incision is made over the top of the shoulder, just lateral to the acromioclavicular joint, extending from the posterior border of the acromion to a point 2 inches below the anterior border of the acromion process The incision is carried to the bone and the acromion is divided in a line midway between the acromioclavicular joint and the top of the acromion By retracting the outer fragment of the acromion and the attached deltoid muscle laterally and downward the subacromial region is visualized After locating the displaced humeral head one expirates it gently from above The attachments of the musculotendinous cuff and the inferior portion of the capsule are severed from the tuberosities and the neck of the humerus and the upper end of the bone is rounded off with bone-biting forceps The cuff and the capsule are transplanted at a lower level completely

enveloping the shaft This step is necessary in order to shorten the rotator muscles thereby compensating for the loss of humeral length The detached portion of the acromion is discarded and the tendinous insertion of the central deltoid fibers is sutured to a more mesial position on the superior surface of the acromion, thus increasing the efficiency of the muscle as an elevator of the arm The skin wound is closed with interrupted sutures and the arm in balanced suspension (Figs 261 and 262)

Postoperative Management. Active motion is encouraged immediately Graduated stooping exercises are begun after from 7 to 10 days Restoration of muscle tone and power is essential in the postoperative regimen With careful management considerable control of the extremity and a surprisingly good range of painless motion may be obtained Active motion executed religiously is the key to optimum function

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